

# MINING



Navigating the  
Global Waters



## TECHNICAL PROGRAM

SME ANNUAL CONFERENCE & EXPO  
CMA 117<sup>TH</sup> NATIONAL WESTERN MINING CONFERENCE  
DENVER, COLORADO | FEBRUARY 15-18, 2015

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# CONTENTS

2014 Program Committee .....	2
CMA.....	4-9
Future SME Meetings .....	312
Health & Safety .....	310
Index: Authors & Chairs.....	297
Keynote Session .....	10
Professional Development Hours ...	311
Sessions-at-a-Glance.....	11-15
Technical Program .....	16
Monday Afternoon .....	16-70
Tuesday Morning.....	71-141
Tuesday Afternoon .....	142-212
Wednesday Morning.....	213-266
Wednesday Afternoon .....	267-296

# 2015 PROGRAM COMMITTEE

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# **COLORADO MINING ASSOCIATION**

## **117th NATIONAL WESTERN MINING CONFERENCE & EXHIBITION**

**February 15-18, 2015**

**Colorado Convention Center  
Denver, Colorado**

### **NAVIGATING GLOBAL WATERS FROM COLORADO: THE BRIDGE FOR WORLDWIDE MINING**

*APPROVED FOR 6 COLORADO CONTINUING  
LEGAL EDUCATION CREDITS*

Successfully navigating mining's global waters requires a sturdy vessel, and a bridge manned by an experienced crew. Colorado's unique infrastructure of mining companies and support organizations provide a bank of technical expertise and resources essential for mining in global arenas. As the SME Annual Meeting addresses worldwide opportunities and challenges, the Colorado Mining Association's 117th National Western Mining Conference & Exhibition will highlight the role that Denver and Colorado companies play in supporting mining throughout the state, the nation, and the world. The conference includes forums addressing the opportunities and challenges facing Colorado mining companies, the activities of Denver-based companies worldwide, and those of the resident organizations and professional societies like CMA and SME that support mining throughout the state, the region and the world. The 117th National Western Mining Conference & Exhibition is about to set sail, bound for opportunities both here and abroad.

*Welcome aboard!*

# COLORADO MINING ASSOCIATION

**CMA Membership Booth Sponsor:  
Pershing Gold Corporation**

**Monday, February 16, 2014**

1:30pm to 4pm

Colorado Convention Center Room 605/607

## **MINING IN COLORADO; MINING IN THE AMERICAS**

*Sponsored by: Climax Molybdenum Company  
AV Sponsored by: American Gypsum Company LLC*

*Session Chairman: Fred J. Menzer, Vice President,  
Colorado Operations, Climax Molybdenum Company  
(A Freeport-McMoRan Company), Empire, Colorado*

Colorado ranks 1st in molybdenum, 4th in the production of gold, and 11th in clean coal in the United States. Notwithstanding the challenges facing Colorado based companies in the form of lower commodity prices, increasingly hostile regulatory actions, and competition from foreign producers, mining in Colorado remains an important and diverse industry. This session – a perennial favorite – will highlight new developments in mining in Colorado and the Americas. Status reports on mine acquisitions and developments in power generation will also be featured.

### **Metals Mining in the Americas**

*Joshua Olmstead, Senior Vice President, Americas,  
Freeport-McMoRan America, Morenci, Arizona*

### **Outlook for Sodium Bicarbonate Production and Exports**

*Rob Scargill, Regional Director, North America, ENIRGI  
Group, Toronto, Ontario, Canada*

### **New Developments in Mining in the North Fork**

*Greg Schaefer, Vice President, Government Affairs,  
Arch Coal, Inc., Gillette, Wyoming*

### **Overview of the Sand, Gravel and Aggregates Industry**

*Todd Ohlheiser, Colorado Stone Sand & Gravel  
Association, Centennial, Colorado*

4pm to 5pm

Colorado Convention Center Room 605/607

## **COLORADO MINING ASSOCIATION ANNUAL MEMBERSHIP MEETING**

*Sponsored by: Western Fuels Association, Inc.*

President's Annual Report to the Membership  
Election of Officers and Directors

# COLORADO MINING ASSOCIATION

**Tuesday, February 17, 2015**

9am to 11:30am

Colorado Convention Center Room 605/607

## **COLORADO MINES THE WORLD**

*Sponsored by: CAP Logistics*

*AV Sponsored by: Knight Piesold & Co.*

*Chairman: Karr McCurdy, President & CEO,  
Behre Dolbear, Greenwood Village, Colorado*

This session will review the activities of Colorado-based mining companies throughout the nation and the world, the activities of companies seeking to expand export potential for Colorado mineral products, and the latest influences on corporate developments, prospects and relocations. The Denver Gold Group represents more than 80 per cent of the world's publicly traded gold and silver companies, holding world class investor forums. Kinross Gold is one of the world's leading gold producers and has recently completed relocation to the Mile High City. Ambre Energy is building infrastructure to support the growing export market for western coal. And the Colorado School of Mines, one of the world's leading research universities and institutions of higher learning for engineering and applied science, is constantly evolving and innovating. Top officials from each of these organizations will outline key opportunities and challenges impacting the industry, and the important role that mining educators will play in preparing the next generation of industry leaders.

### **Mining, M&A Activity and Trends in the Gold Industry:**

#### **What's next?**

*Tim Wood, Executive Director, Denver Gold Group, Denver, Colorado*

#### **Kinross Gold: A Gold Mining Leader Relocates to Denver**

*Lauren Roberts, Senior Vice President – Americas, Kinross Gold Corporation, Denver, Colorado*

#### **The Colorado School of Mines:**

##### **Educating the Next Generation of Industry Leaders**

*Dr. Priscilla Nelson, Department Head and Professor, Department of Mining Engineering, Colorado School of Mines, Golden, Colorado*

#### **Millennium Bulk Terminal Project:**

##### **Expanding the Export Capacity for Western Coal**

*David Carlile, Vice President, Marketing, Ambre Energy NA, Salt Lake City, Utah*

1:30pm to 5pm

Colorado Convention Center Room 605/607

## **ENVIRONMENTAL AND REGULATORY CHALLENGES: PITFALLS, POT AND POLITICS**

*Sponsored by: Western Fuels – Colorado, LLC*

*AV Sponsored by: Holland & Hart LLC*

# COLORADO MINING ASSOCIATION

*Panel Moderator: Robert Comer, Partner, Norton Rose Fulbright US LLP, Denver, Colorado*

This session will explore the environmental, regulatory and political challenges the mining industry is navigating. The current decade has resulted in new initiatives and challenges on every front - from air and water quality to the Endangered Species Act and sage grouse protection, a bird that occupies more than 60 million acres of the western landscape. The legalization of the recreational use of marijuana and efforts to roll back employer zero tolerance policies pose significant safety and legal risks for the industry and its workforce. This industry has charted a course to work where it can and defend where it must. This session will review the most recent developments, as well as the work of our industry associations to preserve mining in the American economy.

## **The EPA Carbon Regulations: Legal Flaws and Other Considerations**

*Peter Glaser, Partner, Troutman Sanders, LLP, Washington, DC*

## **The Expanding Scope of Air Quality Regulation: Proposed Ozone Standards and Other Recent Air Quality Initiatives**

*Garrison W. Kaufman, Of Counsel, Holland & Hart LLP, Denver, Colorado*

## **Cannabis in Colorado, Workplace Safety and CMA Actions**

*Laura Beverage, Member, Jackson Kelly PLLC, and Michael Moberly, Partner, Ryley, Carlock, & Applewhite, PC, Phoenix, Arizona*

## **Endangered Species:**

### **The Expansive Role of Shrinking Species Management**

*Kent Holsinger, Manager, Holsinger Law, Denver, Colorado and Robert Comer, Partner, Norton Rose Fulbright US LLP, Denver, Colorado*

## **CMA ENVIRONMENTAL STEWARDSHIP BANQUET**

### **HYATT REGENCY • CENTENNIAL AB**

*Sponsored by: Bowie Resource Partners LLC, Cripple Creek & Victor Gold Mining Company - AngloGold Ashanti (Colorado) Corp., Mountain Coal Company, LLC*

*Banquet Wine: Resource Capital Funds*

*Banquet Cocktail: Behre Dolbear,  
Forsberg Engerman Company*

*AV Sponsored by: Check-6, Inc.*

**6pm Reception**

**7pm Banquet**

**8pm**

**Remarks by Shaun McGrath**  
Regional Administrator, Region 8  
Environmental Protection Agency  
Denver, Colorado

# COLORADO MINING ASSOCIATION

## ENVIRONMENTAL STEWARDSHIP AWARDS PRESENTATION

### BANQUET PRESENTATION

*Karl Mecklenburg, Former Denver Broncos Captain  
and All-Pro Linebacker*

- Drafted in 1983 to the Denver Broncos, retired in 1994
- Played in six Pro Bowls
- His 79.5 sacks is the second highest in franchise history
- Inducted to the Denver Broncos Ring of Fame in 2001

**Wednesday, February 18, 2015**

9am to 11am

Colorado Convention Center Room 605/607

## COLORADO: GROUND ZERO IN THE GREAT RESOURCE DEVELOPMENT DEBATE

*Chairman: Stuart A. Sanderson, President, Colorado  
Mining Association, Denver, Colorado*

During the past decade, the mining industry has won major victories in the legislature and the courts, preserving, defending and upholding state laws allowing industry to develop the very best and most modern technologies in resource extraction. In addition to defeating one ballot initiative and several bills that would have banned modern mining, CMA's win in the landmark case, CMA v. Summit County, preserved state regulatory authority over mining in lieu of patchwork local bans. Anti-mining activists, however, continue to try to impose additional restrictions on mining through legislation and ballot measures. Although a last minute compromise kept off the 2014 ballot, a measure that would have allowed local governments to supersede state law and ban virtually any business activity, the controversies continue.

This session will feature prominent speakers from across the academic, business and political spectrum and provide you with the latest insights on what these measures mean for future resource development. The speakers will also review the 2014 election results and how those results will shape Colorado's political future.

### **State and Local Fracking Regulations Confront the Takings Clause**

*Jan G. Laitos, John A. Carver, Jr. Chair in Natural  
Resources and Environmental Law, Sturm College of Law,  
Denver, Colorado*

# COLORADO MINING ASSOCIATION

## **What the Fracking Controversies Mean for Mining**

*Mike King, Executive Director, Colorado Department of Natural Resources, Denver, Colorado*

## **Citizen Initiatives in Colorado – What Lies Ahead**

*Rick Reiter, Executive Director, Coloradans for Responsible Reform, Denver, Colorado*

## **Legislative Efforts to Restrict Modern Mining Technologies in Colorado**

*Dianna Orf, Orf & Orf, PC, Denver, Colorado*

## **How the Fall Elections will Shape Mining's Future**

*Richard Wadhams, Independent Political Consultant, Littleton, Colorado*

Noon to 2pm

## **CLOSING AWARDS LUNCHEON**

*Sponsored by: Hogan Lovells US LLP, Jackson Kelly PLLC, Peabody Energy - Twentymile Coal LLC, Pinnacol Assurance, Royal Gold, Inc., Wagner Equipment Co.*

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## **COLORADO DIVISION OF RECLAMATION, MINING & SAFETY**

## **COLORADO MINED LAND RECLAMATION BOARD**

## **SAFETY AND RECLAMATION AWARDS**

*Speaker: Honorable Bill Cadman  
President, Colorado State Senate  
Senate District 12  
Colorado Springs, Colorado*

## **AWARDS PRESENTATION**

# 2015 SME Keynote Session

**Monday February 16, 2015**

**8:30am, Four Seasons Ballroom 2 - 4**

**Colorado Convention Center**

**Denver, Colorado**

## **“The Mine of the Future: Forecasting Opportunities and Challenges for the Global Mining Industry”**

Taken as a whole the international mining industry is softening as the global economy expands at a more moderate pace and mine capacity may have outstripped demand in the short term. However, in the individual mining sectors of coal, metal, industrial minerals and aggregates, opportunities await for smarter companies that are meeting their own domestic and international challenges by opening new markets, creating new products, cutting costs and improving efficiencies. This multi-industry sector panel will address both the opportunities and challenges that lie ahead for each mining sector.

### **Moderator**

**Peter Bryant**, Senior Fellow & Honorary  
Co-founder, the Kellogg Innovation Network

### **Speakers:**

**Red M. Conger**, President Americas, Freeport  
McMoRan Inc.

**Gwenne A. Henricks**, Vice President  
Product Development & Global Technology  
and CTO, Caterpillar Inc

**Bryan Galli**, Group Executive and Chief Marketing  
Officer, Peabody Energy

**Dean Gehring**, President & CEO, Rio Tinto Minerals

**Barry Hudson**, Director of Aggregates Northern  
Europe, HeidelbergCement,

# SESSIONS-AT-A-GLANCE

Sessions are arranged by day, chronologically, alphabetically

## Monday, February 16 · Afternoon

<u>Session</u>	<u>Page</u>	<u>Room</u>
Bulk Material Handling:		
Advances in Component Designs	<b>16</b>	709
Coal & Energy: The Best of Ground Control	<b>23</b>	501
Coal & Energy: Carbon Management	<b>18</b>	502
Coal & Energy: Coal Preparation I	<b>20</b>	504
Coal & Energy: Ventilation Best Practices I	<b>26</b>	503
Diversity: How Diversity and Inclusion Drives Business Results - Discussions of Real World Experiences	<b>29</b>	111
Dreyer Lecture (1:30)	<b>16</b>	710
Environmental: Effective Mine Closure Exit Strategies	<b>29</b>	105
Environmental: Groundwater and Underground Mining	<b>32</b>	107
Environmental: Treatment Technologies	<b>34</b>	106
Fundamentals of Professional Ethics	<b>38</b>	712
Industrial Minerals and Aggregates: Aggregates: Reserve Estimation and Mine Planning	<b>39</b>	102
Industrial Minerals and Aggregates: Industrial Minerals: Minerals for Oil Field Applications	<b>41</b>	104
Let's Get Technical: How Mining Companies Are Raising Capital and Can Lower Costs	<b>44</b>	112
Mineral & Metallurgical Processing:		
Plenary Session	<b>45</b>	601-603
Minerals Education Coalition: Telling the Mining and Minerals Industry's Story	<b>45</b>	109
Mining & Exploration: Management: Future of Mining: Leadership or Roadkill: Roundtable	<b>48</b>	705
Mining & Exploration: Management: Professional Responsibility and Safety	<b>49</b>	707
Mining & Exploration: Operations: Asset and Maintenance Management	<b>51</b>	706
Mining & Exploration: Operations: Mine Reconciliation	<b>54</b>	705
Mining & Exploration: Technology: Stope Design Technologies	<b>56</b>	708
Mining & Exploration: Technology: Underground Mining Projects & Innovation I	<b>58</b>	704
Mining & Exploration: Technology: Utilizing Simulators for Mine Equipment Training	<b>61</b>	703
My First Five Years in Operations	<b>63</b>	711
Research: Focus on Innovation in Mining Industry	<b>66</b>	507

# SESSIONS-AT-A-GLANCE

Sessions are arranged by day, chronologically, alphabetically

## Tuesday, February 17 • Morning

<u>Session</u>	<u>Page</u>	<u>Room</u>
Bulk Material Handling: Improvements in Conveyor Maintenance and Safety	<b>71</b>	709
Coal & Energy: Coal Preparation II	<b>73</b>	504
Coal & Energy: Ground Control Case Studies	<b>75</b>	503
Coal & Energy: Mining Research and Development	<b>77</b>	501
Coal & Energy: Underground Mining Processes and Practices	<b>81</b>	502
Coal & Energy: Ventilation Best Practices II	<b>84</b>	505
Environmental: Responsible Mining Environmental and Social Risks I	<b>86</b>	105
Environmental: Sustainable Reclamation/Remediation	<b>90</b>	107
Environmental: Water Treatment I: The Problem of Dissolved Salts	<b>93</b>	106
Industrial Minerals and Aggregates: Advances in Industrial Minerals Beneficiation International I	<b>96</b>	102
	<b>99</b>	108
International Mining Education Collaboration Opportunities for the Future	<b>102</b>	104
Mineral & Metallurgical Processing: Plant Design	<b>103</b>	708
Mineral & Metallurgical Processing: Separation: Leaching	<b>108</b>	710
Mineral & Metallurgical Processing: Separation: Flotation: Fundamental Aspects	<b>105</b>	711
Mineral & Metallurgical Processing: Separation: Simulation and Modeling	<b>111</b>	712
Mining & Exploration: Building a Safety Culture	<b>115</b>	702
Mining & Exploration: Geology: Mineral Deposits I	<b>117</b>	705
Mining & Exploration: Operations: Hardrock Underground	<b>120</b>	703
Mining & Exploration: Technology: Information Systems Integration for Decisions Support	<b>122</b>	707
Mining & Exploration: Technology: Reliability & Availability, Are you Getting It?	<b>125</b>	704
Mining & Exploration: Technology: Technology Developments and Implementation in Rock Mechanics and Ground Control	<b>127</b>	706
Research: Next Generation Innovation in Mining Industry	<b>130</b>	507
The Business Case for Standard Guidelines in the Current Mine Operations Environment	<b>134</b>	109
UCA of SME: Energy Pre Developed Longwall Recovery Room I	<b>136</b>	111
Valuation I: Lessons Learned	<b>138</b>	112

# SESSIONS-AT-A-GLANCE

Sessions are arranged by day, chronologically, alphabetically

## Tuesday, February 17 • Afternoon

<u>Session</u>	<u>Page</u>	<u>Room</u>
Bulk Material Handling: Trends and New Technology	<b>142</b>	709
Coal & Energy: Breathing Air Supplies I	<b>143</b>	504
Coal & Energy: Developments in Health and Safety	<b>146</b>	501
Coal & Energy: Dust Control I	<b>148</b>	502
Coal & Energy: Mine Planning	<b>151</b>	505
Coal & Energy: Surface Mining Processes and Emerging Issues in Reclamation	<b>153</b>	503
Environmental: Materials Characterization: Advancing that State of the Art	<b>156</b>	105
Environmental: Responsible Mining Environmental and Social Risks II	<b>158</b>	107
Environmental: Water Treatment II: Arsenic, Selenium and Other Contaminants	<b>162</b>	106
Industrial Minerals and Aggregates: Health & Safety	<b>164</b>	102
Industrial Minerals and Aggregates: New Developments in Clay Minerals and Applications	<b>166</b>	104
International II	<b>172</b>	108
Mineral & Metallurgical Processing: Comminution I: Circuit Design and Applications	<b>174</b>	711
Mineral & Metallurgical Processing: Plant Design and Optimization	<b>178</b>	708
Mineral & Metallurgical Processing: Separation: SX/IX/EW	<b>183</b>	710
Mineral & Metallurgical Processing: Remediation and Secondary Processing: Secondary Processing	<b>181</b>	712
Mining & Exploration: Geology: Mineral Deposits II	<b>169</b>	705
Mining & Exploration: Management: Mineral Economics	<b>186</b>	706
Mining & Exploration: Operations: Hard Rock Open Cut	<b>189</b>	702
Mining & Exploration: Operations: Underground Mining: Challenges of Today	<b>191</b>	707
Mining & Exploration: Technology: Mine Discrete System Simulation	<b>194</b>	703
Mining & Exploration: Technology: Technology Innovations in Mine Production Systems	<b>197</b>	704
Operators Session	<b>212</b>	601-603
Optimization of Mining Complexes and Mineral Value Chains	<b>201</b>	109
Research: NORA Safety and Health Research for Small Mines	<b>204</b>	507

# SESSIONS-AT-A-GLANCE

Sessions are arranged by day, chronologically, alphabetically

## Tuesday, February 17 • Afternoon

<u>Session</u>	<u>Page</u>	<u>Room</u>
UCA of SME: Energy Pre Developed Longwall Recovery Room II	<b>207</b>	111
Valuation II: Case Studies	<b>209</b>	112

## Wednesday, February 18 • Morning

<u>Session</u>	<u>Page</u>	<u>Room</u>
Coal & Energy: Mining Innovations and Improvements	<b>213</b>	504
Coal & Energy: Underground Mining Innovations	<b>216</b>	503
Coal & Energy: Ventilation Innovations I	<b>218</b>	501
Coal & Energy: What I Wish I Would have Learned in School	<b>223</b>	502
Environmental: Responsible Mining Environmental and Social Risks III	<b>225</b>	106
Environmental: Sustainable Outcomes from Effective Stakeholder Engagement	<b>229</b>	107
Environmental: Water Treatment III: Arsenic, Selenium and Other Contaminants	<b>232</b>	105
Industrial Minerals and Aggregates: Innovation in Water and Energy Savings	<b>235</b>	102
Mineral & Metallurgical Processing: Comminution II: Mechanical and Electrical Developments	<b>238</b>	711
Mineral & Metallurgical Processing: Research and Characterization	<b>240</b>	709
Mineral & Metallurgical Processing: Separation: Flotation: Industrial Applications	<b>243</b>	710
Mineral & Metallurgical Processing: Separation: Pyrometallurgy	<b>247</b>	712
Mineral & Metallurgical Processing: Student Poster Session	<b>249</b>	708
Mining & Exploration: Geology: Mineral Resource Estimation	<b>250</b>	707
Mining & Exploration: Management: MSHA	<b>253</b>	705
Mining & Exploration: Operations: Innovations in Open Pit Mining Operations	<b>254</b>	706
Mining & Exploration: Operations: Underground Mine Ventilation	<b>257</b>	704
Mining & Exploration: Technology: New Design Concepts and Technologies in Mine Ventilation	<b>260</b>	703
Mining & Exploration: Technology: Underground Mining Projects & Innovation II	<b>264</b>	702

# SESSIONS-AT-A-GLANCE

Sessions are arranged by day, chronologically, alphabetically

## Wednesday, February 18 • Afternoon

<u>Session</u>	<u>Page</u>	<u>Room</u>
Coal & Energy: Breathing Air Supplies II	<b>267</b>	504
Coal & Energy: Dust Control II	<b>269</b>	501
Coal & Energy: Mine Emergency Response	<b>271</b>	503
Coal & Energy: Ventilation Innovations II	<b>272</b>	502
Mineral & Metallurgical Processing: Remediation and Secondary Processing: Tailings	<b>275</b>	710
Mineral & Metallurgical Processing: Separation: Physical Separation	<b>278</b>	708
Mining & Exploration: Geology: Geotechnical Engineering/Geotechnical	<b>281</b>	703
Mining & Exploration: Management: General Management	<b>284</b>	706
Mining & Exploration: Operations: Mine Planning and Geotechnical Interactions	<b>287</b>	702
Mining & Exploration: Technology Electronic Safety Technologies	<b>290</b>	704
Mining & Exploration: Technology: Managing Global Technology and Knowledge Transfer	<b>293</b>	707
Mining & Exploration: Technology: Predictive Maintenance: Technology and Practice	<b>294</b>	705

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from your mobile device**

## DREYER LECTURE

1:30 PM • Monday, February 16 • 710

*Bob Kellie, Reno, NV*

**Monday, February 16**

**Afternoon**

### **Bulk Material Handling: Advances in Component Design**

**2:00 PM • Monday, February 16 • 709**

*Chair: T. Burchett, Rexnord*

**2:00 PM**

### **Introductions**

**2:05 PM**

### **Real Time On-conveyor Analyzer Considerations in Plant Design**

*H. Kurth; Scantech, Underwood, QLD, Australia*

Real time analyzers allow material flows to be diverted based on the measured quality of flow increments (typically two to five minutes). Therefore waste increments can be removed from plant feed and effectively replaced with ore. This may reduce the amount of feed required to be treated to produce the expected product tonnage and hence a smaller, lower cost plant can be built compared to a traditional design. Where mined ore meets the Direct Shipping Ore quality requirement a large proportion of the ore can bypass the beneficiation process. One plant diverts approximately one third of its mined ore in this way. This can significantly alter the materials handling system design requirements to attain the required product output. The implications for the design may not be known until after the plant is built and operating. Reviewing the performance of analyzers in existing plants can allow significant design changes to be considered when plant expansions and new plants are planned for similar orebodies. This paper uses experience at an existing site to propose a broad model for future design considerations.

**2:35 PM**

### **Latest Modulated Controlled Braking Technology for Mining Applications**

*R. Schmidt; Svendborg Brakes A/S, Denver, CO*

3-Stage Digital Modulation technology (similar to Sigma/Delta, but improved) now replaces Pulse Width Modulated method for controlled brake systems. This new development offers several new performance advantages such as Modulation based on actual pressure feedback (closed loop pressure control), Pressure

based parking sequence, New 3-Stage digital modulation, Open loop braking mode (no speed input needed), Five segment S-braking curve, Multiple startup sequences possible, Two levels over-speed detection, Bus communication as standard, Optimized distributed I/O system structure (reduces commissioning time significantly). Future Braking systems will be able to control multiple conveyor brake systems instead of having one for each conveyor

**3:05 PM**

## **The Importance of Properly Sizing a Belt for Specific Mine Applications in the Early Stages of Site Development**

*T. Felts; Caterpillar Inc, Hillsville, VA*

This discussion details technical and financial results around the importance of sizing one's belt system at the early stage of the mine development process. At times, sizing the belt can become an afterthought, and as a result a belt system may be installed simply because it works, not necessarily because it is the best option or fit for the application. This case study looks at the engineering benefits, such as the cost benefit ratio of early state sizing, optimization of spare part consumption and application sizing benefits for capital cost savings, and the financial results of initial startup cost vs. long term cost savings.

**3:35 PM**

## **Variable Speed Direct Hydraulic Drive applications and its recent Technical Developments for the Mining and Bulk Material Handling Industry for various applications**

*A. Amin; Hagglunds Drives Inc, Columbus, OH*

This paper describes the concept and principle of operation of Direct Hydraulic Drive using Low Speed High Torque Hydraulic motor without any intermediate gearing. It provides education of some unique features and technical advantages resulting in a very reliable and modern drive system for today's growing demand for the continuously operating industry's toughest demand. It covers benefits relating to productivity, performance and reliability, guide lines for maintenance, future capacity expansion possibilities. Examples of some of the popular applications in Mining and Material handling like Conveyors, Feeders, BWR, Crushers, Ball mills, Kilns etc.

## Coal & Energy: Carbon Management

**2:00 PM • Monday, February 16 • 502**

*Chair: M. Mohanty, Southern Illinois University Carbondale, Carbondale, IL*

**2:00 PM**

### Introductions

**2:05 PM**

### Addressing Climate Change in Mine Permits and Planning

*A. Lundin<sup>1</sup> and J. Renne-Malone<sup>2</sup>; <sup>1</sup>Environmental, Operations and Construction, HDR, Englewood, CO and <sup>2</sup>Engineering, HDR, Denver, CO*

Over the past several years, a number of legal findings and events have led to regulatory actions by the Environmental Protection Agency (EPA) and the Council on Environmental Quality (CEQ) regarding climate change and how NEPA documents should address the issue. The CEQ recently denied a 2008 petition to include climate-specific provisions in CEQ's NEPA regulations with the finding that that climate change is already within the scope of impacts that should be considered. Without clear guidance, federal agencies vary greatly in how they address climate change in permits and NEPA documents, leaving the agencies open to litigation and project proponents vulnerable to costly delays. This paper examines a number of emerging regulations, and varying federal agency approaches to addressing climate change within permits and NEPA documents and offers a path forward on how to meaningfully and efficiently address climate change in mining permits and NEPA.

**2:25 PM**

### Results from Two Carbon Sequestration and Enhanced Gas Recovery Pilot Tests in Unconventional Reservoirs

*N. Ripepi, A. Louk, E. Gilliland and M. Karmis; Mining Engineering, Virginia PolyTech Inst State U, Blacksburg, VA*

Storing carbon dioxide (CO<sub>2</sub>) in unconventional gas reservoirs, such as unmineable coal seams and organic shale formations, can provide a significant option for mitigating carbon emissions while simultaneously enhancing gas recovery (EGR). Utilization of existing legacy wells can enable CO<sub>2</sub> storage while adding reserves and extending the life of these gas fields. This paper will present results from two field projects funded by the US DoE. 510 tons of CO<sub>2</sub> were injected into a legacy horizontal shale gas well in Morgan County, TN and were allowed to soak for four months. The injection well was brought back on-line as a huff-and-puff test with positive results showing an increase in gas and natural gas liquids production. Characterization and monitoring activities are on-going for a planned 20,000 ton CO<sub>2</sub> test where three legacy vertical coalbed methane (CBM) wells

in Buchanan County, VA, involving multiple thin stacked coal seams, will be utilized. This paper will present preliminary results from the CBM injection project.

**2:45 PM**

## **Coal Mine Methane Developments in the United States and Globally**

*J. Somers; Climate Change Division, USEPA, Washington, DC*

Methane is a potent greenhouse gas and coal seams often contain significant quantities of methane. Methane emissions from coal mining activities constitute approximately 8% of total global human-related methane emissions. Coal mines around the world have long recognized that methane is a clean energy resource that can be captured and used productively. The United States has been a leader in coal mine methane (CMM) recovery and use since the 1990's. There are now 15 projects at active underground mines in the U.S., as well as 26 abandoned mine methane projects. These projects are a win-win for the coal companies, project developers and the environment. They provide an added revenue stream for the coal mine and can improve both safety and mine productivity. In 2014, the California Air Resources Board (CARB) Board enacted a new Mine Methane Capture protocol that would generate compliance-grade carbon offsets for mine methane. Also this year, the Bureau of Land Management released an Advance Notice of Public Rulemaking to examine steps to reduce methane from mining operations on public lands. These and other new CMM developments will be highlighted.

**3:05 PM**

15-087

## **Substitution of Water with CO<sub>2</sub> in Fracturing of Coal Bed Methane**

*P. Munjal; Mining Engineering, Indian School of Mines, Dhanbad, India*

Usage of Supercritical CO<sub>2</sub> in place of high pressure freshwater has proven to be a potential breakthrough in the technique of fracturing. Tapping of carbon footprints from feasible sources like industries can be used to manufacture Supercritical CO<sub>2</sub> required for fracking. Supercritical CO<sub>2</sub>, being less viscous than water, creates complex and coherent micro-fractures which can connect many more natural fractures greatly, increasing maximally the fractures' conductivity leading to an increment in production. The better clean-up property of Supercritical CO<sub>2</sub> provides auxiliary benefits of immediate evaluation of fracture zones, usage of an optimized quantity of mesh proppant and elimination of the need of swabbing. Also, Coal has a stronger affinity for CO<sub>2</sub> than for CH<sub>4</sub>. When CO<sub>2</sub> is present, CH<sub>4</sub> on coal is replaced by CO<sub>2</sub>. This also ensures rigorous recovery of gas from the coal beds. Use of Supercritical CO<sub>2</sub> will obliterate many problems as the CO<sub>2</sub> used for fracturing is either sequestered beneath the crust or is recovered at the surface and reused. Therefore, injecting CO<sub>2</sub> into coalbeds achieves not only enhanced CBM recovery, but also greenhouse sequestration underground.

**3:25 PM**

15-067

## **Go Green with Mining Equipment and HVAC systems**

*J. Gibson; Joy Global, Milwaukee, WI*

With the ever increasing price of diesel fuel accompanied by the popular topic of carbon taxes and greenhouse gas emissions, the mining industry is looking to industry specialists to help them with "Going Green." The benefits of a no-idle policy reach far beyond carbon reduction and fuel savings, ranging from decreased maintenance to increased engine life. With products like battery powered A/C systems and diesel fired heaters, going no-idle is easier today than ever before. With both systems being manufactured to withstand the harsh environments of the mining industry, the end user will see a seamless change from conventional belt-driven systems to the future of mobile equipment HVAC.

**3:45 PM**

## **Atomistic Characterization of the Pore-Scale Co-Current and Counter-Current Imbibition in Shales**

*I. Miscovic; Mining Engineering, University of Utah, Salt lake City, UT*

An in-depth understanding of the pore-scale multiphase transport in shales is one of the key factors necessary to ensure maximum hydrocarbon recovery from these low-mobility reservoirs. In this study, molecular dynamics (MD) simulations of co-current and the counter-current imbibition in nanostructured geomatrix are used to study transport phenomena during the process of enhanced gas recovery from shales. Supercritical carbon dioxide (scCO<sub>2</sub>) and methane are used as injected and a displaced fluids, respectively, while quartz, clay, and organic matter are used to realistically represent shale matrix structure and account for the effect of the surface forces. The ClayFF force field is selected to accurately describe shale-scCO<sub>2</sub> and shale-methane interactions, whereas scCO<sub>2</sub>-methane interaction is defined by the Lennard-Jones 12-6 (LJ) potential. The transport properties that govern the imbibition mechanism in shales are evaluated for different pore sizes, ranging from 5 nm to 10 nm. First, the diffusion coefficients of scCO<sub>2</sub> and methane are evaluated. Next, the penetration of injected scCO<sub>2</sub> in the nanopores and corresponding displacement of methane are determined.

## **Coal & Energy: Coal Preparation I**

**2:00 PM • Monday, February 16 • 504**

*Chairs: B. Arnold<sup>1</sup>, Preptech, Inc., Apollo, PA*

*T. Ghosh<sup>2</sup>, University of Alaska Fairbanks, Fairbanks, AK*

**2:00 PM**

## **Introductions**

2:05 PM

## **Performance Evaluation of Multi-Gravity Separations in a Three-Product Dense Medium Cyclone**

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

Coal preparation plants are required in some cases to produce a high-grade product using a low specific gravity cutpoint. For these situations, a second high gravity separation would be desirable to generate a middle-grade product that can be utilized for electric generation. A research program has been conducted to evaluate the potential of achieving efficient separations at two different specific gravity cutpoints in a single stage using a 3-product dense medium cyclone. The variations in the cutpoint and process efficiency values were quantified as a function of the feed medium specific gravity, feed medium-to-coal ratio and feed pressure using a 3-level experimental design program. The results indicate the ability to effectively treat coal over a particle size range from 6mm to 0.15mm in a single 20mm diameter unit while achieving a low specific gravity cutpoint and a high cutpoint up to 2.1.

2:25 PM

15-045

## **Studies of Characteristics and Models to CH<sub>4</sub>, CO<sub>2</sub>, N<sub>2</sub> Adsorption under Atmospheric Stage**

*H. Wen, Z. Li, J. Deng and L. Ma; Xi'an University of Science and Technology, Xi'an, China*

Taking the long flame coal, gas-fat coal and anthracite as samples, we tested the adsorption quantity to single component gas of N<sub>2</sub>, CO<sub>2</sub> and CH<sub>4</sub> under atmospheric pressure phase at different temperatures. Then we analyzed the adsorption characteristics and models of different metamorphic coals. The results show that metamorphic grade, temperature and gases species are main factors to adsorption quantity of coal. The higher and lower metamorphic grade of coal have greatly influence on adsorption capacity while moderate grade of coal has opposite result. The coal adsorption amount to three single component gases under the same experimental condition is CO<sub>2</sub>> CH<sub>4</sub>> N<sub>2</sub>. The simulation precision order of four adsorption models is quadratic curve model > Freundlich isotherm model > Langmuir model > logarithmic curve model. Quadratic curve model and Freundlich isotherm model both can accurately describe the adsorption behaviors of N<sub>2</sub> and CH<sub>4</sub>, different isothermal adsorption curve of CO<sub>2</sub> needs two kinds or more models to describe. This has a reference value to the study of adsorption characteristics and models to single component gases.

2:45 PM

## **Numerical Modeling of an Air-based Density Separator: Comparative Analysis Between K-epsilon and RSM Turbulence Models**

*T. Ghosh<sup>1</sup>, R. Honaker<sup>2</sup> and A. Salazar<sup>3</sup>; <sup>1</sup>Mining and Geological Engineering, University of Alaska Fairbanks, Fairbanks, AK; <sup>2</sup>Mining Engineering, University of Kentucky, Lexington, KY and <sup>3</sup>Giffin Inc., Auburn Hills, MI*

The modern air-based density separator achieves effective density-based separation for particle sizes greater than 6 mm. Parametric studies conducted with a laboratory scale unit to upgrade low rank coal have demonstrated the applicability to finer size fractions of 6 mm to 1 mm. However, there is a lack of fundamental understanding of the separation process which can be provided using numerical modeling techniques. Using CFD modeling techniques, the separation process was numerically modelled using K-Epsilon and RSM turbulence formulations and validated using experimental dataset. The results prove that the effect of fine coal vortices forming around the riffles act as a transport mechanism for higher density particle movement across the table deck resulting in 43% displacement of the mixed-phase particles and 29% displacement of the high density particles to the product side. The velocity and vector plots show high local variances of air speeds and pressure near the feed end and an increase in feed rate results in a drop in deshaling capability of the table.

3:05 PM

15-121

## **Studies on the Role of Organic/Inorganic Polyacrylamides in Fine Coal Flotation**

*O. molatlhegi, S. Khatibi and L. Alagha; mining engineering, Missouri University of Science and Technology, Rolla, MO*

In the present study, the effect of organic/inorganic (hybrid) polyacrylamide polymer on fine coal flotation was investigated. Raw coal samples contain about 37% of ash-forming mineral at a feed size of  $-75 + 38 \mu\text{m}$  were subjected to flotation tests in the presence of in-house synthesized hybrid  $\text{Al}(\text{OH})_3\text{-PAM}$  at different polymer dosages and pH values. Results show a significant improvement in both combustible recovery and ash rejection at 1 ppm polymer dosage. Further improvement of combustible recovery was obtained when flotation was performed at pH 5. Interfacial properties of coal particles before and after flotation were examined through electrokinetic (zeta potential) measurements of coal/water slurries. Zeta potential vs. pH curve were established and compared. In the case of raw coal/water slurry, zeta potential-pH curve resembles the ash-forming minerals (silica and clays) more than coal. After  $\text{Al}(\text{OH})_3\text{-PAM}$ -assisted flotation, the zeta potential of froth/water slurry shifted to more positive values point which strongly indicates significant removal of ash-forming minerals from coal by  $\text{Al}(\text{OH})_3\text{-PAM}$ .

## Coal & Energy: The Best of Ground Control

2:00 PM • Monday, February 16 • 501

Chair: *S. Tadolini, Orica, Georgetown, OH*

2:00 PM

### Introductions

2:05 PM

### The Implementation of Rock Mechanics into a Multiple Level Limestone Mine

*D. Newman; Appalacian Mining & Engineering, Inc., Lexington, KY*

In the 1950s, an underground limestone mine in the Camp Nelson Formation was developed from an outcrop exposure. Based upon the production requirements and an attempt to maximize limestone recovery from a single level, a variety of pillar dimensions and three mining heights (28 feet, 68 feet and 83 feet) were developed. This was sufficient prior to reaching the mineable extent of Level 1. Level 2 introduced previously unknown ground control challenges. These included: Pillar spalling and a significant back fall on the Level 1 - Level 2 decline, laminated immediate back and the need to bolt the back on Level 2, delamination of the back adjacent to the Level 1 - Level 2 decline resulting in bolt shearing, and floor heave in isolated areas of Level 2, multiple level interaction, the need to design pillars based upon numerical modeling as columnization between Levels is infeasible, and water inflow as the mine approached a river. The efforts to implement rock mechanics were re-focused as Level 2 approached its mineable limit and the initial attempt to drive a decline to Level 3 was unsuccessful.

2:25 PM

### FlexKnot: An Innovation in Roof and Rib Surface Control

*S. Tadolini<sup>1</sup>, A. Bhagwat<sup>1</sup> and D. King<sup>2</sup>; <sup>1</sup>Orica, Georgetown, KY and <sup>2</sup>Bekaert Corporation, Van Buren, AR*

Surface control can prevent the falls of ground between primary roof support systems and rib support. Using existing industrial products, and adopting them for mining applications, has historically attained surface control in underground mining. However, the latest innovative solution, a revolutionary wire mesh product, is designed specifically for underground mining applications jointly by Bekaert and Orica. This knotted wire mesh, FlexKnot™ 2500 and FlexKnot™ 3500, uses smaller gauge, higher tensile strength wires, than a chain link fence or welded wire mesh. The higher tensile wire enables the mesh to achieve greater ultimate load-bearing capacity, with significantly lower overall weight. Test results illustrate the comparisons of the new FlexKnot with traditional 8- and 10-gauge welded steel mesh. The FlexKnot is superior in deflection, load-bearing capacity, and stiffness—categories that are critical in achieving safer surface control. It also offers enhanced corrosion resis-

tance because of the galvanized coating applied on the individual wires prior to the knotting process. Case studies from underground coal mine installations will be presented.

**2:45 PM**

## **Fiber-Reinforced Polymer Rockbolts for Ground Control in a Strong Jointed Rock Mass**

*S. Mohanty, T. Vandergrift and T. Ross; Agapito Associates, Inc., Grand Junction, CO*

The construction of underground hydrocarbon storage caverns in Jurong Island, Singapore, is nearing completion. The facility, located beneath the seabed of Banyan Basin, is comprised of five storage caverns with a storage capacity of approximately 1.5 million cubic meters. In addition to the storage caverns, various access and operations tunnels are required to support the facility. Among these are water curtain galleries to ensure that hydrostatic pressures in excess of hydrocarbon storage pressure are maintained in the rock mass surrounding the storage caverns. Conventional steel rock bolts with resin polymer grout were considered for ground control. However, the construction contractor proposed using fiber-reinforced polymer (FRP) bolts with cement grout due to the corrosive hydrologic environment, weight and handling considerations, local construction preferences, and the requirement to have a cavern design life of 50 years. FRP bolts with cement grout were ultimately chosen for the project. The FRP bolting system has proven to be very successful, with no ground failures experienced where systematic FRP bolting has been applied.

**3:05 PM**

## **Time Dependent Mining-Induced Subsidence Measured by Differential Interferometric Synthetic Aperture Radar**

*J. Wempen and M. McCarter; University of Utah, Salt Lake City, UT*

Differential Interferometric Synthetic Aperture Radar (DInSAR), a satellite-based remote sensing technique, has been demonstrated as a potentially practical method for measuring mining induced surface subsidence. Unlike traditional methods of subsidence monitoring, DInSAR has the capacity to generate subsidence data on a regional mining scale with a relatively high data density. Using DInSAR to evaluate subsidence over large regions with relatively long time scales has the potential to help quantify the impact of subsidence in the mining region, and provide a means for validating whole-mine geotechnical models. In this study, nine pairs of interferometric data from the Japanese Advance Land Observing Satellite (ALOS) were processed using DInSAR to generate displacement maps for a group of trona mines in southwest Wyoming. The data cover a time span from December 2007 to March 2011. The maximum subsidence for one of the mines totaled 1.3 meters for this period. Cumulative DInSAR displacement maps show the development of subsidence over time. In this mining region, surface subsidence is generated primarily by extraction of trona using retreating longwalls.

3:25 PM

## **Calibration and Application of Photogrammetric Monitoring of Rock Mass Behavior in Underground Mining**

*D. Benton, S. Iverson, J. Johnson and L. Martin; CDC NIOSH OMSHR, Spokane Mining Research Division, Spokane, WA*

Photogrammetric methods are advancing rapidly and show considerable promise as a ground control research tool. The ability to quickly capture three-dimensional geometry, especially changes in geometry, in underground and laboratory settings is a significant advance from point distance measurements. Photogrammetry is being applied in both of these settings as part of the NIOSH ground control research. This paper describes these applications and the equipment and software being employed. It also describes tests conducted to quantify the accuracy of these systems. Accuracy varied with system specifics and procedures. A factory-calibrated camera produced results within 1/32 of an inch, plus 0.04%. A user-calibrated camera was found to be less accurate, at 1/20 of an inch, plus 0.24%. These calibrations demonstrate that photogrammetry can produce research quality measurements in laboratory and mine settings.

3:45 PM

## **Mitigation of a Massive Sandstone Channel's Impact on Longwall Face Evaluation and Enhancement of Hydraulic Fracturing Technique**

*J. Lu, M. Van Dyke, D. Su, G. Hasenfus and L. Stull; Consol Energy, Canonsburg, PA*

This presents the evaluation, enhancement and comparison of two hydraulic fracturing techniques which were employed to mitigate the impact of a massive sandstone channel on two successive longwall faces. The hydraulic fracturing technique and Longwall Visual Analysis (LVA) software were initially employed to mitigate the impact of thick, massive sandstone roof during mining of longwall Panel 21. Improved longwall face conditions and productivity were observed as Panel 21 mined through the sandstone channel. However, moderate sandstone fractures and falls at the face were still present in areas where hydraulic fracture influence was not present. Based on the mining experience in Panel 21, and site-specific roof geology in Panel 22, a modified and more effective hydraulic fracturing program was employed. Fewer well-placed holes were drilled, and larger volume of water was pumped into each hole in order to propagate the individual horizontal pancake fractures over a larger area, thereby enhancing caving and relieving face pressure caused by overhang of the massive sandstone.

## Coal & Energy: Ventilation: Best Practices I

2:00 PM • Monday, February 16 • 503

Chairs: **J. Brune**<sup>1</sup>, Colorado School of Mines, Golden, CO  
**H. Dougherty**<sup>2</sup>, Virginia Tech, Newport, VA

2:00 PM

### Introductions

2:05 PM

15-099

### Modeling Leakage though Utilization of Modern Software for a Historical Silver Mine

*J. Brune*<sup>1</sup>, *C. Pomeroy*<sup>1</sup>, *H. Mischo*<sup>2</sup> and *J. Weyer*<sup>2</sup>; <sup>1</sup>Colorado School of Mines, Golden, CO and <sup>2</sup>TU Bergakademie Freiberg, Freiberg, Germany

Mining began in the Erzgebirge region of Saxony, Germany more than 800 years ago. In one of the larger mines, Reiche Zeche, operated by the Technische Universität Bergakademie Freiberg (TU BAF), these old workings today offer an underground laboratory for teaching, research projects and university outreach activities. Since the workings are so vast and contain century-old unmapped production stopes, ventilation becomes difficult as unknown and unmapped leakages take air away from where it is needed most. It is estimated that two-thirds of the air entering the intake shaft leaks through unknown drifts. Researchers discuss the development of a procedure to estimate the leakages in order to establish a functioning mine ventilation model for planning and emergency management purposes. The leakages are quantified by measuring in- and outflows of drifts, and modelled using modern visualization software. Researchers are using the model to develop a correct ventilation air balance showing where these leakages are occurring, and how much air is lost in each area. The final ventilation model will then be used to simulate air flows and escape scenarios in case of fire or water inundation.

2:25 PM

### Ventilation on Demand: Optimal control of main fans in an intelligent network

*S. Back*<sup>2</sup>, *T. Neff*<sup>2</sup> and *A. Lahm*<sup>1</sup>; <sup>1</sup>Engineering, TLT-Turbo, Inc, Akron, OH and <sup>2</sup>Sales, TLT-Turbo GmbH, Zweibrücken, Germany

**ABSTRACT:** For several years the term “Ventilation on Demand” (VOD) is discussed in the mine ventilation community. The obvious benefits in energy efficiency are proven, with energy savings of up to 55% recorded, but yet the VOD concept is not an established standard up to now. The main reason being that it is an exceptionally wide spreading topic, which encompasses many involved subsystems such as main fans, auxiliary fans, regulators, sensors, control and monitoring systems, and other mining equipment. This paper will focus more on assisting the phenomenon of VOD, by optimally controlling main fans, in

order to achieve the required energy savings. The paper seeks to explore the methods of fan control highlighting the advantages and disadvantages of the more recently favoured option of using variable speed drive. It will also highlight the many benefits of using in-flight blade pitch adjustment, to control fan output, and thereby having a direct control of expended energy. The paper will show a more workable solution applicable to the mining sector.

**2:45 PM**

15-134

## **Design Considerations for Main Surface Fan Installation**

*A. Haghghat<sup>1</sup> and S. Gillies<sup>2</sup>; <sup>1</sup>Mining & Minerals Engineering, Virginia Tech, Blacksburg, VA and <sup>2</sup>Mining & Nuclear Engineering, Missouri S&T, Rolla, MO*

A study has been undertaken at the Missouri S&T Experimental Mine limestone mine. Available fans for ventilation are a Joy and an Alphair axial fan each of 24 kW and two underground Spendrup booster fans each of 12 kW. Installation of main mine fans on surface entails numerous consideration. The design of a ventilation network in conjunction with the surface and booster fans has been accomplished using Ventsim Visual program software. An exhausting main surface and a booster fan have been used in two segregated part of the network. The mine has had a Joy fan in place for many years. The Alphair 4800 VAX 1800 half blade axial fan has been selected and installed as the other surface fan. Main surface fans have been connected individually to booster fans in series. The Alphair main surface fan has been installed vertically. Four different wiring options and cost estimations for addition of the new main fan to the ventilation network were considered. Three different options have been considered for setting up the Aphair fan on a new shaft. An innovative steel frame design has been used to allow the fan, when necessary, to be moved to the side so that blast pressure does not damage it.

**3:05 PM**

## **Laboratory Studies of Pressure Balancing Techniques to Control Spontaneous Combustion**

*A. Jha<sup>1</sup>, F. Calizaya<sup>2</sup> and M. Nelson<sup>3</sup>; <sup>1</sup>Mining Engineering, University of Utah, Salt Lake City, UT; <sup>2</sup>*

Spontaneous combustion of coal is a serious problem in underground mines having safety and economic implications. One of the control measures to this problem is pressure balancing. Balancing pressure across the gob and working area ensures that the ingress of oxygen towards gob is minimized and combustion of coal is contained to a large extent. This study presents the results of laboratory experiments carried out at University of Utah's coal mine ventilation model. This model includes two working areas, one mine gob and a set of isolation stoppings. The model is ventilated by two fans, one main fan and one booster fan. A compressed air injection system, equipped with control valves, is used to pressurize the gob and maintain it at a pressure slightly higher than that of the workings. During each experiment, fan pressures and stopping re-

sistances are changed, compressed air flow rate regulated, and the differential pressures across the stoppings monitored. These are then used to determine the critical parameters governing the pressure balancing process.

**3:25 PM**

## **Guidelines for Safe Operation of Booster Fans in Coal Mines**

*F. Calizaya and M. Nelson; Mining, University of Utah, Salt Lake City, UT*

This paper presents a summary of basic requirements for the design, installation and operation of booster fans in coal mines, especially in deep and / or extensive mines. The guidelines were prepared based on the standards and regulations adopted by two prominent coal mining countries, the best practices developed by the mining industry, and the applicable standards used in the U.S., for fail-safe operation of main fans. A sample coal mine ventilation problem is solved to illustrate the design principles, the benefits that can be derived by using booster fans, and the potential problems that may arise when the basic requirements are not met. The problem is solved for two ventilation scenarios: (1) using surface fan only, and (2) using a combined surface-booster fan system. A summary of findings from these studies is also presented in this paper.

**3:45 PM**

15-093

## **Optimizing Nitrogen Injection for Progressively Sealed Panels**

*J. Marts, R. Gilmore, J. Brune, G. Bogin, J. Grubb and S. Saki; Mining Engineering, Colorado School of Mines, Golden, CO*

Researchers at Colorado School of Mines have developed computational fluid dynamic (CFD) models to study gas distributions and explosion hazards in longwall gobs. In underground coal mines, methane emitted from surrounding strata mixes with air from active mine workings and may form explosive gas zones (EGZs). Some western US coal mines are also prone to spontaneous combustion (spon com). Insight into oxygen concentrations in the gob is crucial for assessing spon com hazards and mitigation strategies. Nitrogen injection used in conjunction with progressive gob sealing can reduce EGZs and spon com hazards by forming a dynamic seal separating methane in the gob from air that ingresses from the face. This paper describes CFD simulations studying the formation of such dynamic seals by optimizing the nitrogen injection locations. The impact of nitrogen on oxygen ingress and formation of EGZs is discussed. Optimum nitrogen injection quantities and injection locations were determined. Dynamic seal formation is most effective if the headgate nitrogen injection locations are split between the first crosscut inby the face and a second location about 300 m (1,000 ft) further inby.

## **Diversity: How Diversity and Inclusion Drives Business Results – Discussions of real world experience**

**2:00 PM • Monday, February 16 • 111**

*Chairs: **Jessica Kogel**, Imerys  
**Nancy Bingham**, Caterpillar Global Mining*

Join this candid discussion of how diversity and inclusion initiatives are changing the way mining is done from the mining industry, major suppliers and at universities. We'll talk about what is currently working – as well as lessons learned. You'll leave with concrete ideas and action plans for how to better integrate diversity and inclusion initiatives at your organization.

Panelists and perspectives:

**Ben Cordani**, Global Human Resources Director, Caterpillar Global Mining (moderator): Creating an inclusive culture for a global workforce

**Jill Tietjen**, P.E., President and CEO, Technically Speaking, Inc. and President, Board of Directors, National Women's Hall of Fame: Why women's talent is needed to create true innovation.

**Jeannine Carter**, Director of Global Inclusion and Diversity, Newmont Mining: How the D&I Journey can follow the safety journey to become embedded in corporate culture

**Speaker to be named: Imerys** - How a mining company with a growth strategy by acquisition meets the inclusion challenge  
**Dr. Kray Luxbacher**, Virginia Tech: Proactively creating a diverse talent pipeline for the mining industry

## **Environmental: Effective Mine Closure Exit Strategies**

**2:00 PM • Monday, February 16 • 105**

*Chair: **R. Reisinger**, CH2MHill, Englewood, CO*

**2:00 PM**

**Introductions**

**2:05 PM**

**Acceptable, Achievable, Sustainable?  
Assessing Post-Closure Goals at Legacy  
Mine Sites**

*W. Weinig; Montgomery & Associates, Denver, CO*

Closure is now included in the early stages of mine planning and development. Operators can adjust to create sustainable systems that achieve pre-defined closure goals. Legacy mine sites include abandoned, inactive, and operating facilities that

were constructed before the advent of modern closure planning. Several examples illustrate the difficulty of defining appropriate closure goals for legacy sites. At an abandoned underground mine, water quality is impacted by a spring discharging from the workings. An active water treatment system will likely be operated by a county agency in perpetuity. Active closure elements can be less sustainable than passive systems, but were thought to be more protective. Groundwater is impacted in an historic copper-mining district. Setting closure goals for water quality in this area is complicated by pre-existing impacts and overlapping regulatory programs. Other examples include a semi-passive treatment system at a remote, abandoned mine and defining background conditions for re-opening an historic mine. These case studies illustrate the difficulty of setting acceptable, achievable, and sustainable closure goals at legacy mine sites.

**2:25 PM**

## **Creating a Legislative Platform to Allow Mine Closure and Relinquishment**

*M. Thorpe; Golden Star Resources, Toronto, BC, Canada*

The Canada Mining Innovation Council Environmental Stewardship Initiative identified mine closure as an area for innovation that would change the mining business. Of the Canadian jurisdictions, there are a handful that allow for site relinquishment but only one (Saskatchewan) has a functioning relinquishment mechanism. The lack of defined relinquishment criteria can lead to the management of sites in perpetuity. Should the company dissolve or mineral rights leases and/or permits expire, the responsibility for closure and rehabilitation would then revert to the Crown. The development of standardized closure criteria will provide a clear path to achieving the end-goal of relinquishment. In turn, this will provide certainty for operators and stakeholders regarding mine closure, will allow for more progressive rehabilitation planning and implementation, and will help reduce the incidence of abandoned mines accruing to the Crown. This paper examines the opportunity to develop standardized closure criteria and provides a road map for their use in mining.

**2:45 PM**

## **Mine Closure Planning for Economic Value in the Developing World**

*M. Thorpe; Golden Star Resources, Toronto, BC, Canada*

Golden Star Resources operates two gold mines in Ghana, West Africa. As part of the legal requirements within Ghana, every mine must have a rehabilitation and closure plan at the start of operations. As part of our closure and rehabilitation planning, we complete a series of stakeholder consultations aimed at identifying the post closure needs of our communities. Based on this and the successes that we have in our corporate responsibility programs, we then develop an exit strategy for a particular unit of the mine. We have evolved our approach over the past several years so that our stakeholder community consultation is now a key driver for closure planning. We aim to close our tailings impoundments as oil palm plantations, flooded pits as aquaculture and other areas as a mix of farmland and firewood – all of which have been either trialed or tested as part of our on-going efforts. By building our closure plans into our CSR efforts,

we can ensure that our operations leave a lasting positive legacy in Ghana. The paper will present an overview of closure planning and community development associated with the Bogoso and Wassa mines

**3:05 PM**

## **Reducing Closure Costs and Risks: A Cost-Benefit Analysis of Mining and Rehabilitation Methods**

*A. Churr; ERM, London, United Kingdom*

Achieving mine closure and relinquishment is an ongoing challenge. ERM reviewed 57 mines that ceased production between 1945 and 2012. Only five have been relinquished with no further company obligations. The difficulty in achieving closure is often tied to an inability to meet environmental and social commitments made through the life of the mine and changing stakeholder expectations as closure approaches. As such, closure provisions often fall short of the true costs of closure. ERM will present a case study which shows that by changing mining methods, the mine NPV could increase by 20 to 45% by changing the stripping and backfill methods during mining. Also:

- Mines are often overly optimistic about their ability to achieve closure, and the risks are not well understood;
- Continuous engagement with stakeholders over the life of mine is essential in order to identify expectations and interests;
- Rehabilitation must be integrated into the mine plan, rather than a standalone closure plan; and
- Mining performance metrics and incentives should be weighted towards mine plan quality and adherence to mine plan rather than just production to balance short term and long term requirements.

**3:25 PM**

## **Key Strategies for Operation and Closure of Refuse Piles, Coal Ash and Tailings Ponds**

*R. Sweetwood; Burns & McDonnell, Downers Grove, IL*

Reclamation regulation within the mining and power plant industries was created with the intent to release a permitted facility from further obligations if it met certain standards. However, evolving interpretations, changing standards, quilt by proxy, and the onslaught of lawsuits have limited final phase release of tailing ponds, coal slurry ponds, coal ash ponds, or coal refuse piles to a small percentage. Martin (2000) estimated that there are 3,500 tailing impoundments worldwide. There are an estimated 600 coal ash ponds within the United States of America and there are many more coal slurry ponds and coal refuse piles throughout the country. Mineral and Coal Power Plant waste byproducts account for the largest environmental costs within these industries, and without innovative engineering and environmental methods, companies should anticipate that these costs may never cease and final permit release may never occur. Burns and McDonnell has explored three methods that may aid in achieving final release for mining and power plant waste byproduct disposal sites: 1. Environmental Exploration; 2. Consolidate and Isolate; and, 3. Groundwater Diversions.

**3:45 PM**

## **Fiscal Requirements for Managing of Assets with Impending Retirement**

*R. Gilbert; Environment & Infrastructure, AMEC, Minneapolis, MN*

This presentation will discuss different approaches to the management of assets versus complete demolition within a given property that is either; in the course of closure study, is scheduled to be closed, or has already been closed. There are two planning methods that will be discussed during this presentation. The first method involves the planning of fiscal requirements by providing a complete Asset Retirement Study (ARO). An ARO is the legal obligation to perform an activity upon the retirement of a tangible, long-lived asset based on a law, statute or ordinance, a written or verbal agreement between parties, and a promise to a third party. The second method involves the complete execution of the Asset Retirement Study. This method is based in large part on the value of existing commodities (copper, stainless steel, zinc, lead, aluminum, etc.) within the given property. The outcome of this study is to provide a return on investment from the exiting commodities back the owner, which would also include a net-zero demolition cost.

**4:05 PM**

## **What makes for an Effective Mine Closure Exit Strategy? (Panel Discussion)**

*R. Reisinger; CH2M HILL, Englewood, CO*

The final presentation for this session will be a panel discussion of session speakers. The discussion will be guided by a series of questions provided by the session chair as well as the audience and will focus on common ingredients that make for an effective mine closure exit strategy.

## **Environmental: Groundwater and Underground Mining**

**2:00 PM • Monday, February 16 • 107**

*Chair: J. Vanlandingham, Twin Metals Minnesota, St Paul, MN*

**2:00 PM**

## **Introductions**

**2:20 PM**

## **Underground Inflow Estimates and Observations in Support of Groundwater Flow Modeling, Hollister Mine, Elko County, Nevada**

*B. Hart; Brown and Caldwell, Carson City, NV*

Rates of groundwater inflow to the proposed initial exploration decline at the Hollister Mine, in Elko County, Nevada were estimated based on assumed decline advance rates and limited data from surface groundwater characterization boreholes. Inflow estimates for the initial proposed extent of decline development were within approximately 10 percent of the actual inflow rates. Based on the inflow data and refinement of the hydrogeologic conceptual site model, a three-dimensional groundwater flow and transport model was developed for the project permitting. Groundwater inflow rates that occurred as the exploration decline and laterals advanced to the initial proposed extent and beyond were used in the long-term transient calibration of the groundwater flow and transport model. Dewatering effects on the surrounding aquifer systems and the fate of metals that would be transported from the post-mining, refilled mine workings were evaluated with the model.

**2:40 PM**

## **Estimating Groundwater Recharge and Discharge Relationships in Wetlands using Soil Morphology, Plant Community Composition, and Geomorphology Indicators**

*J. Arndt; Environmental Science, Merjent, Inc., Minneapolis, MN*

Recharge and discharge of groundwater associated with a given wetland are important characteristics that can be used to evaluate the impacts of mine development, operation, and closure on wetland functions. Site-specific hydrologic analysis using piezometers can be used to quantify groundwater flow in wetlands; however the analyses are expensive, are difficult to generalize from a point to the whole wetland, and are difficult to relate to meaningful changes in wetland function. Soil morphologic characteristics and hydrophyte plant community dynamics reflect the dominant groundwater flow regime, integrate groundwater recharge and discharge dynamics over time, and inform interpretation of ponding regime. Soils and hydrophytes are determining characteristics of wetland function important when considering mine impacts to wetland functions. This presentation explains the use of soil morphology, geomorphology, and plant community composition indicators to evaluate groundwater recharge and discharge dynamics under baseline conditions in the upper Midwest, and future conditions where mine-induced alterations to wetland hydrology are predicted by sub-regional groundwater modeling.

**3:00 PM**

## **The Value of Good Hydraulic Conductivity Data for Mining Industry Groundwater Flow Models**

*M. Gozdor; Geosyntec Consultants, Temple Terrace, FL*

Groundwater flow models are frequently used in the mining industry to help make decisions regarding permitting, dewatering, operation, and closure. The accuracy and usefulness of a groundwater flow model relies upon the hydrogeological data collected prior to its development and the evaluation of that data. Recognizing that each model parameter has a unique sensitivity, one parameter that is often critical to groundwater flow model development is hydraulic conductivity. Traditionally, hydraulic conductivity has been evaluated via geophysics, pumping tests, and packer tests. However, inappropriate data collection and interpretation can lead to erroneous hydraulic conductivity values and hydraulic conductivity fields. While all models contain some degree of error, erroneous hydraulic conductivity values may generate groundwater flow model results that exceed the limits of allowable risk. This presentation will show several case studies that shed light on the considerations that must be given to hydraulic conductivity testing and data evaluation. Additionally, it will show the impact that improper testing or interpretation can have on groundwater flow predictions for mines.

**3:20 PM**

## **Shale Gas Recovery Modelling of Heterogeneous Systems**

*D. Gabeva; Hydrogeology, DG Consultancy, Brisbane, QLD, Australia*

Extraction of natural gas from organic shales is a complex technological problem, which requires a well-grounded scientific approach to its solution. An inherent property of shale formations is the low permeability. This is the reason to consider the approach of using the hydraulic fracturing for intensification of the shale gas recovery. The paper presents an integrated numerical and stochastic approach for modelling unconventional gas reservoir production from shales, which is developed for two-phase flow and transport in shale gas formations. The study is based on a detail analysis of the factors having impact on the reservoir production capacity, such as fracture spacing, relative permeability, stimulated reservoir volume and adsorbed gas. A special emphasis in the study is placed on the modelling of the heterogeneity of the shale formation and its impact on the gas production by using a stochastic approach.

## **Environmental: Treatment Technologies**

**2:00 PM • Monday, February 16 • 106**

*Chairs: P. Kochunarayanan, Freeport McMoRan Inc, Phoenix, AZ*

*M. Hay, ARCADIS US Inc., Boulder, CO*

2:00 PM

## Introductions

2:05 PM

### **Getting the Lead out (and other Trace Metals) - Solving Mine Water Problems with Peat-based Sorption Media**

*P. Eger; Global Minerals Engineering, Hibbing, MN*

Pilot tests were run at two mines using peat-based sorption media to remove Pb, Zn and Cd. The first pilot was designed to model active (pressurized tank) and passive (biocell) approaches; the second contained only a pressurized tank. At the first site, pH was greater than 7 and contained 1500 ug/l Pb, 100 ug/l Zn and 1.5 ug/l Cd. Both pilots removed over 99% of the lead and reduced all metals to below permit values. The biocell operated for about 9 months and met the permit limit of 11ug/l for 15000bv (bed volumes). When the pilot ended over 25,000 bv had been treated and Pb removal was still over 80%. At the second site pH was also above 7 but zinc was the major parameter of concern. Input concentrations were 465 ug/l Zn, 135 ug/l Pb and 1.9 ug/l Cd. The peat media effectively removed Zn but after 4500 bed volumes the concentration exceeded the permit limit of 160 ug/l. An additional tank of media was installed and successfully reduced all metals to below permit limits; extending the lifetime of the initial tank to over 12,000 bv. Treatment costs ranged from 43 to 90 cents per 1000 gallons; capital costs were less than 50% of a standard chemical treatment plant.

2:23 PM

15-095

### **A New Electrolytic Alternative to Chemical Neutralization**

*P. James and M. Baker; Blue Planet Strategies, Madison, WI*

A new and recently demonstrated application for BPS's versatile DEMET™ dilute source metal recovery and concentrating technology is described. Here DEMET provides an exciting, cost-effective, and greener alternative to conventional chemical (lime and caustic) treatment of target streams for pH adjustment. Although originally developed to better recovery and/or concentrate dissolved metals from dilute streams such as weak PLS (pregnant leach solution), raffinate, heap leach drain down streams, tailings water, and ARD (acid rock drainage), or similar sources, DEMET continues to expand its range of utility to facilitate new and improved ways to utilize our precious mineral resources. The treatment approach and process will be summarized and its key improvements over conventional chemical treatments noted. Recent DEMET treatment of a copper leaching raffinate is discussed. Benefits of the new treatment: 1) Waste reduction, 2) Potential valuable constituent recovery, and

3) Process economics will be highlighted. Treatment results will be presented and their implications for a representative target scenario discussed.

**2:41 PM**

## **Case Study: 19 Years of ARD Mitigation after a Bactericide Application**

*J. Gusek<sup>1</sup> and V. Plocus<sup>2</sup>; <sup>1</sup>Sovereign Consulting Inc., Lakewood, CO and <sup>2</sup>Diamond Engineering, Blairville, PA*

The Fisher site is a backfilled and reclaimed (in 1984) surface coal mine in western Pennsylvania, USA. A post-closure toe seep at the site discharged ARD generated in pyritic rock zones within the backfill into a passive treatment system (PTS). In 1995, sodium hydroxide and bactericide solutions were injected through cased boreholes into the pyritic zones in a two-step process: NaOH solution followed by bactericide. Post-injection, the toe seepage exhibited net-alkaline chemistry. Based on the prevailing wisdom at the time, the effects of the injection event were expected to be temporary. Almost two decades later, the beneficial effects of the two-step injection event persist and bond release for the site is pending. Over 25 years of seep chemistry monitoring data suggest that the steady-state condition of net alkalinity in the seep water entering the PTS may be permanent. The current belief is that the initial suppression of *Acidithiobacillus ferrooxidans* bacterial community with the injected reagents has been maintained by the seasonal infusion of bactericidal organic acids derived from the robust vegetative cover. The situation appears to be self-sustaining.

**2:59 PM**

## **Selenium Attenuation via Reductive Precipitation in Unsaturated Waste Rock: Evidence of a Control on Groundwater Impacts in the Idaho Phosphate Patch**

*F. Partey<sup>1</sup>, M. Hay<sup>2</sup>, G. Leone<sup>2</sup>, G. Davis<sup>3</sup>, J. Schramke<sup>4</sup>, K. Bergholm<sup>1</sup>, M. Hart<sup>1</sup> and C. Guedes<sup>1</sup>; <sup>1</sup>Environmental, Agrium Inc, Soda Springs, ID; <sup>2</sup>Arcadis U.S., Inc, Highlands Ranch, CO; <sup>3</sup>Brown and Caldwell, Golden, CO and <sup>4</sup>Enchemica LLC, Loveland, CO*

Phosphate mining in Southeastern Idaho has resulted in groundwater impacts due to the oxidative release of selenium and sulfide-associated metals from overburden waste rock. Selenium is particularly important given its high mobility and increasing ecological risk concerns. Impact assessments typically involve laboratory saturated and unsaturated column tests with mine site materials. Unsaturated columns are designed to capture constituent release in oxic environments, but it is not yet known whether they adequately capture the wide range of hydrogeochemical conditions encountered in the field. In this study, we compare saturated and unsaturated column results against storage pile-impacted groundwater at the Mountain Fuel, Champ, and South Central Rasmussen Ridge Mines. Field results indicate lower selenium to sulfate ratios in groundwater beneath overburden storage piles relative to areas receiving surficial runoff. It is suggested that selenium released in oxic upper portions of storage piles is attenuated via reduction at

depth in unsaturated, low-oxygen portions of the storage piles. Implications and recommendations for refined laboratory characterization will be discussed.

**3:17 PM**

## **Selective Component Precipitation From Wastewater Streams**

*P. James and M. Baker; Blue Planet Strategies, Madison, WI*

Here DEMET selective and targeted transformation of waste into value-added potentially revenue generating products is presented. Recovery of metal hydroxide precipitates as valuable DEMET treatment byproducts is illustrated with emphasis on iron and aluminum which often occur at appreciable concentrations in many source streams. Although originally developed to better recovery and/or concentrate dissolved metals from dilute streams such as weak PLS (pregnant leach solution), raffinate, heap leach drain down streams, tailings water, and ARD (acid rock drainage), or similar sources, DEMET continues to expand its range of utility to facilitate new and improved ways to utilize our precious mineral resources. Selective iron and aluminum product generation and separation will be discussed along with generation of potential revenue generation from the production obtained. Treatment results for a target mine waste stream will be presented. Economic comparison with conventional lime treatment will also be discussed.

**3:35 PM**

## **Progress in the Use of Biochemical Reactors for Passive Treatment of Selenium**

*J. Bays<sup>1</sup>, R. Thomas<sup>2</sup> and D. Evans<sup>3</sup>; <sup>1</sup>CH2MHILL, Tampa, FL; <sup>2</sup>CH2MHILL, Atlanta, GA and <sup>3</sup>CH2MHILL, Houston, TX*

Pilot studies and full-scale designs by CH2MHILL for mining and power companies and the US Bureau of Reclamation, along with additional projects discovered through professional contacts and continuing review of the literature, have demonstrated that Se concentrations ranging from 10-1000 ug/L have been treated down to 1-10 ug/L. Zero-order volumetric removal rates have spanned a range from less than 10 to more than 30 mg Se per day per cubic meter of substrate. First-order, area-based removal rates show a central tendency of approximately 400 m/yr, depending upon inlet oxidized nitrogen, and vary in response to mass and hydraulic loading rates. Nominal BCR hydraulic residence times range from less than 1 to more than 3 days. Nitrate reduction is a necessary step to achieve effective Se reduction, and is typically accounted for by increasing BCR size. The systems have been shown to maintain satisfactory performance even with maximum inlet flows up to 3x average, and under ambient air temperatures less than 0 deg C. The paper summarizes prospects for passive biochemical reactor treatment of Se and potential constraints for future applications. passive treatment of selenium (Se).

3:53 PM

## Successful In Situ Chemical and Biological Remedy Implementation

*J. Spitzinger<sup>1</sup>, A. Griffin<sup>2</sup>, J. Forbort<sup>3</sup> and G. Rader<sup>4</sup>; <sup>1</sup>ARCADIS US, Inc., Denver, CO; <sup>2</sup>ARCADIS US, Inc., Seattle, WA; <sup>3</sup>ARCADIS US, Inc., Minneapolis, MN and <sup>4</sup>ARCADIS US, Inc., Emeryville, CA*

This presentation will review challenges encountered during implementation of in situ chemical and biological remedies including reduced performance and meeting remedial objectives, as well as the corrective measures implemented in response to those challenges. An understanding of primary and secondary processes driving performance is necessary to meet remedial objectives and operate system within cost constraints. The first example presented involves calcite precipitation and resulting passivation of media within a Zero Valent Iron (ZVI) Permeable Reactive Barrier (PRB) for the in situ treatment of arsenic. An in situ acid flushing rehabilitation program was designed to dissolve calcite and restore the reactivity of the ZVI. The second example shows the effects of a long-term in situ biological remedy designed for reductive precipitation of hexavalent chromium. The remedy generated substantial biomass which accumulated in system infrastructure and was managed with innovative dosing approaches and a proactive maintenance plan to maintain subsurface reagent distribution.

### Fundamentals of Professional Ethics

2:00 PM • Monday, February 16 • 712

*Chair: David M. Abbott, Jr., Chairman AIPG Ethics Committee and member of the AusIMM Ethics Committee Denver, CO*

This session will review the differences between moral/ethical rules and moral/ethical aspirations, the procedure for determining whether an exception to an ethical/moral rule is justified, and the differences between general morals and professional ethics. Case histories will illustrate professional ethics provisions. The SME's Registered Member Code of Ethics will be the main ethics code used with additions from the AGI's 2015 Guidelines for Ethical Professional Content and the SME's 2014 Guide for Reporting Exploration Results, Mineral Resources, and Mineral Reserves. This session will satisfy the ethics requirements of some state licensing boards.

*Mr. Abbott has been writing, giving talks, and presenting short courses about professional ethics for many years including 152 published Professional Ethics & Practices columns for AIPG's The Professional Geologist. He was a member of the committee that drafted AGI's 1999 and 2015 Guidelines for Ethical Professional Content. He spent 21 years as a geologist for the US Securities and Exchange Commission prior to becoming a consulting economic geologist in 1996. He is Registered Member of SME, a Chartered Fellow of AusIMM, and a Certified Professional Geologist by AIPG.*

## **Industrial Minerals and Aggregates: Aggregates: Reserve Estimation and Mine Planning**

**2:00 PM • Monday, February 16 • 102**

*Chairs: K. Kosloski, Newmont Mining Corporation,  
Richmond, VA  
A. Parr, Oldcastle Materials, West Kingston, RI*

**2:00 PM**

### **Introductions**

**2:05 PM**

### **Optimizing Truck Selection Using Discrete Event Simulation: A Case Study of P.J. Keating Co. Lunenburg, MA Quarry**

*R. Gagliano<sup>1</sup> and K. Awuah-Offei<sup>2</sup>; <sup>1</sup>P. J. Keating Co.,  
Lunenburg, MA and <sup>2</sup>Mining & Nuclear Engineering, Missouri  
University of Science & Technology, Rolla, MO*

Longer haul distances can reduce productivity of truck haulage operations as cycle times increase. Larger nominal payloads can be incorporated to remedy this. Proper sizing of equipment is critical to transport material at the lowest possible unit cost. Truck sizing should take into consideration other portions of the process so that bottlenecks are not introduced with the change in truck sizes. Computer simulation (like discrete event simulation) can assist in examining changes in operations at a low cost without any physical changes. This paper presents the use of Arena® to select optimal truck sizes at the P. J. Keating Co. Lunenburg MA Quarry Using Arena® simulation software while considering the impact of truck sizes on primary bin and feeder. A model of the mine's truck-shovel system was built and validated with real production data. The model is used to conduct simulation experiments to evaluate various production scenarios. The results show that operating four 75-ton haul trucks would be the best option as it meets the processing plant's productivity requirements with low wait times at the primary, high utilization of the pit loader, and the lowest cost/ton.

**2:25 PM**

### **Production Scheduling of Limestone Mine for Consistent Supply to the Cement Plant: An Application from Indian Limestone Mine**

*D. Joshi<sup>1</sup> and S. Chatterjee<sup>2</sup>; <sup>1</sup>Mining Engineering, NIT Rourkela,  
Rourkela, India and <sup>2</sup>Mining Engineering, NIT Rourkela,  
Rourkela, India*

Production scheduling of limestone mine is a challenging job because most of the limestone mines are served as captive mine for cement plant. To maintain consistent supply of raw materials to the cement plant, the cement plant management needs to use additives with the raw materials from the captive limestone mine. Therefore, optimising the quality and quantity of the additives is a crucial job to minimise the cost as well as increase the life of the existing limestone mine. In this paper,

mixed integer programming (MIP) was used for optimising the additive quality and quantity. The study was performed from an Indian limestone mine which is a captive mine for the cement plant. Results revealed that if no additives were used, the mine can sustained only for 15 years; however, with additives the mine can supply raw materials for 75 years for the cement plant. The results also revealed that the size of the ultimate pit is significantly small as compared to the ultimate pit obtained after using additives.

**2:45 PM**

## **Real Aperture as Both a Strategic and Tactical Monitoring Tool**

*A. Pienaar and G. Djobouljian; MALA GeoScience USA, Inc, Charleston, SC*

Mining companies have an obligation to support the best mining practices so as to ensure the safety of personnel. Within the context of open cast mining, best mining practices call for the timeous detection of potential rock slope instabilities – making both strategic and tactical slope monitoring an integral part of any mine's slope monitoring program. Radar technology is well entrenched within the mining industry and its implementation, with regard to geotechnical monitoring, is widely regarded as best practice. The effectiveness of Real Aperture Radar as both a strategic and a tactical monitoring tool has been proven on mine sites throughout the world. The Movement and Surveying Radar (MSR) has become a critical element in the early prediction of slope failures in surface mines. The MSR has proven itself as both a strategic and tactical monitoring tool. Real-world case studies - using MSR field data - will provide further insight into what is meant by an integrated monitoring strategy and how effective strategic and tactical monitoring can be achieved using Real Aperture Radar.

**3:05 PM**

## **Benefits of Remote Control Technology on a 988 Loader to Mine Planning and Safety**

*B. Smith; Business Development, Luck Stone, Richmond, VA*

Safety is one of a number of design concerns that all mining operations must never lose focus on. How a company deals with hazards can have a long term impact on stone reserves. Over the years, Luck Stone has changed its mine plan to continue providing a safe environment for our operator. Wider safety benches are left intact, highwalls are shorter than they once were, and scaling is performed more frequently. As a result of these changes, extractable permitted reserves are smaller than they once were. This Presentation describes how a team of Luck Stone Associates with a passion for new ideas joined forces with an open minded vendor to figure out how to extract more stone within the same pit footprint, while still maintaining the highest of safety standards. The result was a successful experiment with a Remote Control Caterpillar 988 Loader.

**3:25 PM**

## **Some Perspectives of Mine Pit Re-Purposing**

*M. Knight; Gannett Fleming Inc., Harrisburg, PA*

Numerous open pit mine re-purposing projects are underway or under consideration in metropolitan areas of the United States. Because these projects contemplate future integration of active mine sites into existing water or waste water infrastructure systems, many involve either public/private or private/private partnerships where agreements, long term commitments and open dialogue guide and influence orderly transition from original to secondary pit use. Public perception and social contract benefits are often realized by the participants in these visionary conversion processes but the best outcomes are achieved when the miner, infrastructure engineer, regulator and end-user work toward common goals. At first glance it might be easy to envision immediate common ground between miners and second generation users. Each party desires the same things: maximum resource extraction; safe operating conditions and efficient reliable infrastructure systems. The reality is that even with such apparent commonality, the details of re-purposing transition from miner to end-user are myriad and the details deserve discussion and deliberate planning.

**3:45 PM**

## **The Latest Developments to VSI Crushers for Heavy Mining Use**

*D. Rodriguez; REMco, Livermore, CA*

In the late 1980's, a new reduction device was introduced to the mining community. This device is generically known as a VSI or Vertical Shaft Impactor. It is an innovative machine which was at the time in its infancy with regard to its use in comminution circuits. Over twenty years have passed since those days and now more is known about the performance and capabilities and shortcomings of these machines. Keeping in mind that comminution circuits in mining tend to be large, complex and expensive; the search for high reduction, low cost and reliable equipment continues. Today REMco, Rock Engineered Machinery Company, of Livermore, California has developed a new series of VSI machines capable of continuous reliable round the clock service with remote digital machine control and recording and heretofore unachieved low consumables costs. In this presentation, Damian Rodriguez, President and C.E.O of REMco will introduce attendees to the REMco OreMax.

## **Industrial Minerals and Aggregates: Industrial Minerals: Minerals for Oil Field Applications**

**2:00 PM • Monday, February 16 • 104**

*Chairs: B. Pruett, Imerys, Milledgeville, GA*

*A. Mahmoudkhani, Clariant, The Woodlands, TX*

**2:00 PM**

## **Introductions**

2:05 PM

## High Temperature Oilwell Cementing: Challenges and Opportunities

*A. Mahmoudkhani; Global Innovation, Clariant, The Woodlands, TX*

There are specific requirements for cements used for application in which downhole temperatures in oil and gas wells exceed 100 °C. The main challenge with this type of cements is to be able to control fluid properties during pumping operation. Cement setting and bonding to casing and formation is very critical for success of zonal isolation. Due to increasing industry demands for enhanced mechanical properties of cement blends, there is a need to improve its understanding on how to engineer the right product for a given application. When bottom hole temperature reach 300 °C or above, cement will go under various phase transitions which adds another complexity to cement job design. In this paper we present common industrial minerals and cement additives used for high temperature applications and discuss challenges and opportunities oilfield industry is currently dealing with.

2:23 PM

## The Use of Borates in the Oil and Gas Industry

*D. Schubert, J. Owen and M. McCray; U.S. Borax Inc, Greenwood, CO*

Abstract will be uploaded later

2:41 PM

## Proppant Prospects for Industrial Minerals: Ceramic Proppant Supply and Demand Trends in a New Era of Unconventional Resource Development

*M. O'Driscoll; Industrial Minerals Consultant, Leatherhead, United Kingdom*

The quest for low cost, clean, and efficient energy sources has assisted the drive for the exploration and development of unconventional oil and gas resources worldwide, especially shale gas and shale oil resources. Advances in hydraulic fracturing and horizontal drilling technologies has enabled this resource exploitation. Imperative for this industry has been the evolution and development of proppants in hydraulic fracturing – mainly natural silica sand (frac sand), but also ceramic proppants manufactured from kaolin and bauxite. However, the supply of ceramic proppants is limited, especially outside North America, and meeting demand from the existing and anticipated boom in shale gas exploration and development is challenging. There are only certain industrial minerals that can meet ceramic proppant specifications, and their commercial development, until recently, has been somewhat limited. This paper highlights ceramic proppant raw materials, main sources, and supply to the oilfield industry – especially new markets in the Middle East, China, Asia-Pacific, South America – as we enter a new era of resource development which relies heavily on proppant utilisation.

**2:59 PM**

## **Ceramic Proppants**

*J. Flowers; IMERYS, Houston, TX*

In spite of what we hear in the media today, hydraulic fracturing is not a new technology. The first frac jobs were pumped in the late 1940's using crude oil and gelled diesel. Shortly thereafter the idea of adding a solid to fluid to help hold open or prop open the fracture was born. The first "proppant" was nothing more than river sand collected from the banks of a nearby river. Today the choice of proppants is larger than ever before and range from low quality sands to almost perfectly spherical ceramic beads. Of course the increase in proppant strength and conductivity came with increased cost. So how does the engineer decide what to pump in their well? This presentation will discuss the vast array of available proppants, the role of proppants in a fracture and what factors should be considered when selecting the best material for the job.

**3:17 PM**

## **A Geological Overview of Frac Sand in the United States**

*M. Benson and A. Wilson; Central Mineral and Environmental Resources Science Center, U.S. Geological Survey, Denver, CO*

A new mineral rush is underway in the upper Midwest of the U.S., especially in Wisconsin and Minnesota, for deposits of high-quality frac sand that the industry calls "Northern White" sand or "Ottawa" sand. This specialized type of natural sand is added to the fracking fluids that are injected into unconventional oil and gas wells during hydraulic fracturing. The current frac sand mining surge has been driven by the boom in unconventional oil and gas production that has been spurred by expansion of hydraulic fracturing and horizontal drilling. The principal sources of these premium sands are the Ordovician St. Peter Formation and the Cambrian Jordan, Wonewoc, and Mount Simon Formations. Additional frac sand sources in the south-central region include the Cambrian Hickory Member of the Riley Formation in Texas that is referred to as "Brown" or "Brady" sand, and the Ordovician Oil Creek Formation in Oklahoma. In addition to frac sand mining and distribution, a new alternative proppant industry has emerged that produces coated sand and synthetic beads. These combined industries have a robust market that is fast-growing in the U.S. and around the world.

**3:35 PM**

## **Where in the United States is the naturally occurring Frac Sand?**

*A. Wilson and M. Benson; Central Mineral and Environmental Resources Science Center, USGS, Lakewood, CO*

The upper Midwest is the major supplier of frac sand in the U.S. Frac sand consists of natural sand grains that conform to specifications defined by the petroleum industry. Principal sources are the Ordovician St. Peter Formation and the Cambrian Jordan, Wonewoc, and Mount Simon Formations. Additional sources include the Cambrian Hickory Member of the Riley Formation in Texas, and the Ordovician Oil Creek Formation

in Oklahoma. Other sands show promise locally, but most of these require additional preparation or manufacturing. A digital geologic map shows the rock units that are sources of naturally occurring frac sand. The map was compiled from state-scale geologic maps, augmented locally with more detailed mapping. As the state maps over-represent the areas of interest by combining frac sand producing formations with other lithologic units, modifications were made to our map to remove many of the non-target units. Superimposed on the geology are the locations where frac sand is being mined from these units.

## Let's Get Technical: How Mining Companies Are Raising Capital and Can Lower Costs

**2:00 PM • Monday, February 16 • 112**

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

Leading experts will discuss trends and sources of capital and the importance financiers and investors place on management managing and reducing capital, operating and maintenance costs. The past several years have been tough for mining companies to raise capital. The equity markets dried up, valuations are way down, relative to the flurry of 6 years ago. Management, Owners and Investors need to understand the pros and cons of a New or Alternative capital sources from private equity, streaming and royalty firms, debt and alternative capital sources. Are companies able to increase productivity, lower costs, better manage risks to fund exploration, development, equipment, and expansion? How?

- This panel of will focus on capital sources, optimizing, reducing costs and project risk
- What sectors look the best? Are most active? Are improving? Is M&A the answer?• What are and who has provided the principal capital sources in recent years?
- What are pros and cons of alternative sources, e.g. private equity, royalty, streaming?
- Can productivity be increased? Operating, capital and maintenance costs reduced?
- Are these options available for you? What is the outlook? Will 2015/6 be better?

*Speakers: Tim Alch, Chair & Moderator, Vice Chair of NY Section of SME & Co Chair of SME's Mining*

*Finance Conference:*

- BNP Paribas, **Michael Drabble**, Vice President, Corporate Finance - Mining, Minerals and Materials Group - Trends in Industrial Minerals M&A
- Duff & Phelps, LLC, **Edward Lee**, Managing Director, Valuation Advisory – Non Traditional Mine Finance: A Perspective About Streaming and Royalty Finance
- Headwaters MB, **Joel Schneyer** Headwaters, Managing Director: Minerals, Capital & Advisory Practice -

- A Primer re Gold Valuations and Development Costs and Private Equity's Role in Frac Sands
- McKinsey & Company, MineLens, Richard Sellschop, Expert Partner - The Importance of and Case for Mining Productivity Improvement
- MISOM Technologies Inc., Dr. Sean Dessureault, President, The Use of New Technology, Data and Systems to Manage Risk and Reduce Mining Costs
- OREN Inc., Benjamin Cox, Managing Director & Founder - Overview of Recent Mining Financings Trends
- OSIssoft, Andrew Fanara, Sustainability Strategist - Managing Use and Cost of Water and Power
- Shearman & Sterling, Cynthia Urda Kassiss, Partner Financing Options in Current Market: Lessons Learned

**2:00 PM**

## Introductions

### Mineral & Metallurgical Processing PLENARY SESSION

**2:00 PM • Monday, February 16  
601 - 603**

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**Phil Walker**, Winnemucca, NV

**Richards Lecturer**

**Rick Honaker**, University of Kentucky, Lexington, KY

**Wadsworth Lecturer**

**David B. George**, Kennecott Corp, Salt Lake City, UT

### Minerals Education Coalition: Telling the Mining and Minerals Industry's Story

**2:00 PM • Monday, February 16 • 109**

*Session Convener:* **C. Dale Elifrits**, Northern Kentucky University, Highland Heights, KY

*Chairs:* **I. Peterson**, SRK Consulting, Reno, NV  
**M. Garska**, MT Tech, Calipatria, CA

**2:00 PM**

## Introductions

**2:05 PM**

## **Why Caterpillar Made a 25 Commitment to Mining Education – and What is Happening Today**

*N. Bingham; HR, Caterpillar Global Mining, Oak Creek, WI*

In 1990, Caterpillar was working closely with the mining industry with an expanded line of trucks and products made for the industry. But they also recognized the challenges facing mining because of public and educational perceptions. Caterpillar talked to teachers as well as the industry and created “Common Ground”, a mining educational program that has been seen by over 20 million people. In 2004, Caterpillar continued this commitment by developing the next generation of educational material, “Ground Rules” which has also had profound impact on teachers and students. In this session, Caterpillar will talk about the value of the partnership with the mining industry – one that goes far beyond the products and services they provide.

**2:25 PM**

## **Newmont Mining Corporation’s Community and Educational Outreach Successes in Nevada**

*M. Korpi; Newmont Mining Corporation, Elko, NV*

Newmont’s success in building sustainable operations is based on the Company’s value of demonstrating leadership in safety, stewardship of the environment and social responsibility throughout all phases of the mine-life cycle. From the exploration phase through operations and reclamation/closure, stakeholder interactions are critical in shaping shared value for communities, governments, and the general public. Newmont has successfully operated mining facilities in Nevada for over 50 years. Support and understanding of the mining operations by stakeholders are important to continued operations and the development of new projects. Newmont’s engagement programs and activities with stakeholders focus on several key areas including: education and conservation, community volunteering, community investment and environmental management. These are all conducted in an open, honest and transparent process with stakeholders. Newmont was previously recognized by the US Department of the Interior Bureau of Land Management with its “Hard Rock Mineral Community Outreach and Economic Security Award”.

**2:45 PM**

## **Mining Education Outreach: In Arizona and Using Minerals Education Coalition Materials**

*P. Wilkinson; Lowell Institute for Mineral Resources, University of Arizona, Scottsdale, AZ*

The Mining Foundation of the Southwest has been funding an outreach program since 2009, first through the ADMMR and now through the Lowell Institute at the U of A. The program focuses on educating middle - high school students about the modern mining industry, the value of mined products, and recruiting students into the U of A mining engineering program. It uses a mixture of presentation formats and hands on activi-

ties, reaching over 7000 students per year in classroom settings. Materials used for the program come from a variety of sources: original materials; professional societies; state, federal and foreign government materials; and corporate materials. The most successful programs are a combination of sharing factual information and then providing a hands-on activity for the students. Presentations on careers in the industry are also frequently requested. The SME booklet on careers is an excellent resource and the videos available from Canada on careers are remarkable. Educating people about our industry is challenging and rewarding, requiring new and updated materials. The MEC has been and will be providing new materials for all of us to use now and in the future.

**3:05 PM**

## **Dig Into Mining - Freeport-McMoRan's Approach**

*A. Harmon; Freeport-McMoRan, Phoenix, AZ*

Effective mining education outreach occurs when a comprehensive strategy is employed. Freeport-McMoRan has engaged with partners at all levels to integrate the message of mining to a multitude of stakeholders. This presentation will highlight several of Freeport's partnerships including: Dig Into Mining in partnership with Discovery Education, MineZone in partnership with Paradise Valley Unified School District and the Morenci SME Section partnership with local schools.

**3:25 PM**

## **The More You Dig: It All Starts With Mining**

*J. McCandless; American Exploration & Mining Association, Spokane, WA*

TheMoreYouDig (TMYD) is a public outreach campaign created by the American Exploration & Mining Association (AEMA) to promote the benefits of modern mining and educate the public, particularly young professionals, Congressional staffers, and college students, on how mining makes our modern lives possible. We also inform college students about the many professional opportunities in the mining industry. TMYD uses well established social media, web, and grassroots platforms to communicate its message. Through daily posts on Facebook and Twitter and a fully-formed website featuring a weekly blog, a variety of educational resources, and opportunities to learn about careers opportunities in the mining industry, TMYD is telling the story of mining and its importance to society. Seasonal campus events at colleges and universities give TMYD a grassroots outlet to promote our campaign and offer students an opportunity to meet with AEMA's member companies, a valuable chance to network with experienced industry professionals. Our efforts have resulted in an established, growing audience and a diversified, vibrant campaign.

**3:45 PM**

15-028

## **CEDAR Coal Education Program: Experiences and successes reaching out from the coal industry to K-12 and the public**

*G. Robertson and D. Mudd; CEDAR, Holden, WV*

This presentation will show how CEDAR (Coal Education Development And Resource) has promoted coal education to teachers and students (K-12 grades) in Kentucky, Virginia and West Virginia. CEDAR began in 1993 in one state, one county. In 2014, the CEDAR program was offered to teachers and students in three states, thirty-two counties. This program provides opportunities for teachers and students to learn about the many benefits the coal industry provides each of them in their daily lives. CEDAR provides grant money and materials to teachers and the teachers create and develop a state approved curriculum lesson plan to teach according to the guidelines established by CEDAR. As a result of these lesson plans, students have the opportunity to develop Coal Fair Projects in one of seven categories: Art, English, Math, Music, Science, Social Studies, and Technology/Multi-media. These projects compete at the school level and then regionally for each CEDAR program. The CEDAR Regional Coal Fair provides students an avenue to show case their individual talent in specific areas, tie this into learning about coal, and coal related benefits.

## **Mining & Exploration: Management: Future of Mining: Leadership or Roadkill: Roundtable**

**2:00 PM • Monday, February 16 • 705**

*Chair: L. Freeman, CH2M HILL, Denver, CO*

**2:00 PM**

### **Introductions**

**2:05 PM**

## **The Future of Mining: Our Evolving Role in Global Society - A roundtable discussion of visions for mineral recruitment, education and talent development to better serve global society**

*L. Freeman<sup>1</sup>, P. Highsmith<sup>6</sup>, M. Poulton<sup>2</sup>, M. Karmis<sup>3</sup>, P. van der Veen<sup>5</sup> and M. Hitzman<sup>4</sup>; <sup>1</sup>Downing Teal Inc, Denver, CO; <sup>2</sup>University of Arizona, Tucson, AZ; <sup>3</sup>Virginia Tech, Blacksburg, VA; <sup>4</sup>Colorado School of Mines, Golden, CO; <sup>5</sup>Mining Consultant, Washington, DC and <sup>6</sup>Resource Advisory Corporation, Denver, CO*

Panelist will present talking points supported by a few slides, followed immediately by discussion among panelists and the audience. The goal of this session is to change the 'view point' on the relevance of mineral sciences and engineering in society

with implications to recruitment, education, talent development (and funding). Over the next two generations we will see unprecedented increases in global affluence, resulting in unprecedented demand for all commodities including mined materials. The resource industries have the responsibility to provide the necessary natural resources. In doing so we have an opportunity to lead global sustainability by demonstrating how to 'share' global resources across cultural and stakeholder silos. Elements of this topic were introduced in a paper recently published by the National Academy of Engineering. Supplying Society with Natural Resources. The Future of Mining – From Agricola to Rachel Carson and Beyond. Freeman and Highsmith, 2014 <http://www.nae.edu/Publications/Bridge/110801.aspx> Panel: Leigh Freeman, Patrick Highsmith, Mary Poulton, Mike Karmis, Peter van der Veen, Murray Hitzman (tentative)

## **Mining & Exploration: Management: Professional Responsibility and Safety**

**2:00 PM • Monday, February 16 • 707**

*Chair: T. Camm, Montana Tech, Butte, MT*

**2:00 PM**

### **Introductions**

**2:05 PM**

15-076

### **Management Challenges in Nurturing a Safe Work Environment**

*T. Camm; Mining Engineering Dept., Montana Tech, Butte, MT*

As engineers, we are trained to use logical, rational problem solving to insure our mines operate at maximum efficiency. We tend to use the same technical approach to design safety into all mining systems. This works well for machines, but not so much for the human component. Recent insights in the field of behavioral economics provide useful ideas for addressing the fact that we are driven by emotions more often than by rational thought. Understanding the nonrational aspect of human behavior is an important piece of any safety system design.

**2:25 PM**

### **Improving Equipment Design through Industry-OEM Engagement – EMESRT**

*B. Scholz; Technical Services, Newmont Mining Corp, Greenwood Village, CO*

Since 2006 the Earth Moving Equipment Safety Round Table (EMESRT) has been working to influence the industry's major OEMs to reduce risk in equipment design. The EMESRT member companies decided on three initial strategies for improving design: -Engage with OEMs to discuss the problems, not prescribe solutions -List the major hazards needing greater de-

sign consideration -A task based risk assessment in the OEM design process Over the past 8 years as many as 15 global mining companies have delivered the following messages to 7 major OEMs -Designing beyond standards -Balancing design & behavior -Task based design review -Involving end user Recently EMESRT evolved its approach into an equipment procurement process - EMESRT Design Evaluation for Equipment Procurement - and presented to the major OEMS twice in 2012. In 2014 EMESRT has taken on the Vehicle Interaction (collision) challenge. Workshops have been held to examine the methods of reducing risk and defining problems – both at site and in the OEM design. EMESRT has demonstrated its value; however, is not a short term project. The industry must continue to engage with the OEMs to continue to reduce risk in equipment and technology design.

**2:45 PM**

## **Improving Safety and Reducing Risks with Prevention through Design**

*J. Treen; Mining, Stantec – Mining, Tempe, AZ*

The Hierarchy of Controls is an effective system to eliminate or minimize exposure to hazards and unsafe conditions. The controls progress from the most effective (Elimination) to the least effective (PPE). This concept is well known to mining operators but is less understood as you move away from operations. Training designers on the hierarchy is as important as training operators to perform their tasks safely. The keys to success include creating and reviewing the process systems, educating employees so they are capable of understanding and following the system, and holding individuals accountable. Although this sounds like a simple process, it requires focused effort, especially when engineering firms may not have the operational experience in how their designs are utilized, let alone experience in safety management. This paper focuses on how to use the Elimination, Substitution, and Redesign phases from the Hierarchy of Controls to reduce risks by Prevention through Design. It also discusses how to create a safety culture within an engineering firm where personal injuries are rare but the implementation of the designs can have a lasting effect on the client's site safety.

**3:05 PM**

## **Exposure engagement: Taking mining safety beyond Behavior**

*B. Austin and M. Hajaistran; BST, Ojai, CA*

High-performing mining organizations focus on exposures as the trigger for action and the measure of change. This presentation explores what an exposure focus means, how to initiate a shift toward exposure elimination, and the ways leaders can develop a workforce capable of adapting to changes in exposure.

**3:25 PM**

15-129

## **Safely Secure Fasteners in Critical Mining Applications**

*J. Pereyra<sup>2</sup> and M. DeMarco<sup>1</sup>; <sup>1</sup>Sales, Superbolt Inc., Salt Lake City, UT and <sup>2</sup>Marketing, Nord-Lock Inc., Oakland Park, FL*

It is vital that bolted joints holding subassemblies together remain secure. A loose or broken bolt can be catastrophic for mining equipment or people around it, whether they are working or not. Fasteners used to secure bolts should resist loosening caused by vibrations and dynamic loads, but remain easy to remove during maintenance. When a threaded fastener is subjected to vibration, the movement causes a lowering of friction against the threads and a loss of preload. The fastener will vibrate loose and it could fall out. To eliminate unsafe bolt loosening, specially designed lock washers create a wedge-locking effect in the joint. For large diameter bolts, bolting methods can include heavy, dangerous equipment and be time consuming, increasing worker fatigue. Multi-jackbolt tensioners are designed to emphasize increasing worker safety, by tightening in pure accurate tension, eliminating thread galling, and reducing routine maintenance. By tightening small jackbolts within a larger nut, a strong axial force is generated. The jackbolts create a high thrust force with little torque input. When conditions are extreme, fasteners secured safely for worker safety is at the forefront.

## **Mining & Exploration: Operations: Asset and Maintenance Management**

**2:00 PM • Monday, February 16 • 706**

*Chair: R. McMillan, Tero Sys, Phoenix, AZ*

**2:00 PM**

## **Introductions**

**2:05 PM**

## **Maintenance Developments for Cost and Efficiency Improvements**

*S. Purchon; Mining & Construction, Babcock International, London, United Kingdom*

Mining companies rely upon fleets of equipment and vehicles to extract and transport products from the earth. These fleets are often diverse mixes of equipment, from a broad range of suppliers. Delivering a leaner, more efficient fleet is a proven means of reducing the cost per tonne of a mining operation. Simon will examine the challenges of maintaining a diverse fleet in the mining sector and will show how implementing a recognised approach to asset management will optimise any fleet. The talk will outline how a proactive approach to maintenance can deliver high availability by reducing unscheduled downtime. It will show how a recognised, independent fleet selection protocol procures the right asset for every job and provides greater visibility

of the through life costs of each new asset. The talk will also convey the benefits of utilising management information gathered through telematics and analysed using a recognised asset management system. By the end of the presentation, delegates will understand how a recognised asset management approach can drive efficiencies, help to reduce the costs and provide the foundations for a safe operational environment.

**2:25 PM**

## **Using the new ISO55000 Asset Management Standard to help improve efficiency and performance at all levels of your organization**

*G. Lifton; CH2MHILL, Cochrane, AB, Canada*

The new ISO55000 Asset Management Standard was published in early 2014 and its development has involved industry leaders from around the world. Some may question the usefulness of these standards since at first glance they appear high level. In the new ISO standards you won't find details on how to develop your asset inventory or how to perform condition assessments. It is not a how-to guide, but the documents are focused on ensuring all parts of the organization are aligned to achieve common objectives, consistently and sustainably, over time. While the practice of Asset Management has been steadily evolving, this is the first time that a specific International Standard has been published. This standard will appeal to a broad range of asset owners, especially to those asset intensive industries who are seeking greater external confidence in their organization from their stakeholders along with improving their reputation. This paper will take the audience through how ISO55000 can benefit their organizations, along with lessons learned from several PAS55 (the predecessor specification to ISO55000) projects completed across North America.

**2:45 PM**

## **Robotic Technologies in the Mining Industry**

*C. Campbell; Machinery Automation and Robotics, Silverwater, NSW, Australia*

The mining industry is transitioning from a capital intensive expansion phase to a productivity driven operational improvement future. To stay competitive, the industry is in need of innovations to boost efficiency, safety, and overall productivity. The objective of this paper is to present developed automated robotic systems that can address major operational issues in the mining industry. Technology solutions for material handling, heavy vehicle, and primary crusher maintenances are discussed. With robotic technologies, maintenance can be performed on conveyors while they are loaded and operational, thus increasing productivity and operational safety. With growing haul truck fleets, tyre maintenance and fuel costs are proving to be the highest expense factors. Significant gains can be made with robotics by decreasing the time to complete the tasks and increasing utilisation of haul trucks. GET on shovels & other excavating equipment is critical to production and can lead to costly downtime if broken from the shovel without detection. A smart technology solution can provide condition monitoring which will deliver new levels of control over components of heavy mining shovels.

**3:05 PM**

## **Towards an Integrated Framework for Asset and Process Health Monitoring and Optimization on a Milling Circuit**

*M. Mills<sup>1</sup>, P. Smit<sup>2</sup>, J. Rademan<sup>2</sup> and F. Rousseau<sup>2</sup>; <sup>1</sup>Intelligent Platform-Mine Performance, General Electric, Lisle, IL and <sup>2</sup>Mine Performance - Consultant, GE Intelligent Platform, Stellenbosch, South Africa*

In mining operations, it is widely accepted that strategies to drive operational goals must revolve around improving plant availability, reliability and process efficiency. In this paper, an integrated solution framework for reducing process variability, increasing process efficiencies and maximizing plant availability and reliability is discussed within the context of a typical milling circuit. The framework exploits a real-time analysis “gap” evident in production operations that prevents timeous identification of equipment and process failures. This is achieved by leveraging predictive analytics for equipment health monitoring, control loop monitoring and advanced regulatory control solutions towards enhanced process performance, improved asset management and regulatory compliance. The framework provides for early and actionable warnings on equipment and process degradation using real-time operational data.

**3:25 PM**

## **Case Study- Supply Chain and Managing Critical Part to sustain underground maintenance program**

*A. Rai; Barrick Turquoise Ridge Inc, Winnemucca, NV*

Direct order parts being received at the warehouse in the past have sat on the shelf waiting to be picked up (in some cases) extended periods of time. In order to alleviate space and storage constraints at the warehouse and to be better stewards of the materials we order, a new set of standards are being implemented for direct order parts. There are four categories of direct order parts: 1. Unplanned or emergency parts orders, which are any part, ordered of a unit-down situation. 2. Consumables which are parts or materials ordered for general use. These parts are typically not charged to a work order. 3. Planned parts, which are for repairs being planned for the future. 4. Closed work orders, these are parts that are still in the warehouse and the work order has been closed. The new process will be discussed and presented.

**3:45 PM**

15-006

## **Asset Performance Control in Mineral Processing**

*P. Martin; Industrial Automation, Schneider Electric, Foxborough, MA*

As the speed of business has continued to increase over the last decade, the focus on real-time control of the performance of both stationary and mobile assets has become an increasing priority. Traditionally the maintenance team has been focused

on the management of the availability of assets while the operations team has been focused on the throughput of those same assets. Typically operations and maintenance teams worked almost independently in spite of the fact that they were both working with the same assets. Part of the problem has been their traditional performance measures which have often been diametrically opposed. Recent advancements in the area of real-time performance measures and decision support have helped to drive higher levels collaboration between operations and maintenance leading to real-time asset performance control and higher levels of business performance. This paper will explore the forces driving the need for changes, present an effective approach to the definition of the most appropriate business performance measures, examine the effectiveness of contextualized real-time decision support resulting in asset performance control.

## **Mining & Exploration: Operations: Mine Reconciliation**

**2:00 PM • Monday, February 16 • 705**

*Chair: L. Elgert, AMEC, Calgary, AB*

**2:00 PM**

### **Introductions**

**2:05 PM**

### **Quantifying Dilution during Resource Estimation and Ore Control**

*G. Seibel; AMEC, Denver, CO*

Internal dilution may be added during construction of the resource model, but the amount added is commonly not quantified or coordinated with that added to the reserve model by the mining engineers. Thus, it is not uncommon for the mining engineer to assume that dilution is built into the resource model, and the resource modeler to assume that dilution will be included by the mining engineers. This may result in over- or under-estimating the amount of dilution and may have a significant impact on the economics of the project. Similarly, dilution may be added during the construction of ore control models, but the amount of dilution added is commonly not passed on to the mining engineers during mining. Also, the term internal dilution may have different meanings. To the resource modeler it usually means the amount of waste added into the resource model through techniques like compositing and soft contacts, while mining engineers commonly understand it to be waste blocks inside an ore panel that are shipped as ore. This presentation will look at the main factors in controlling and quantifying the amount of dilution added during the construction of resource and ore control models.

**2:25 PM**

## **Applying Ore Loss and Dilution to the Resource Model**

*K. Hanson; Mining & Metals, AMEC, Eagle, ID*

The mining engineer is responsible for applying modifying factors to the resource model to account for ore loss and dilution encounter during mining. Too often, the modifying factors for ore loss and dilution are misapplied or not applied at all. This paper discusses a systematic approach for applying ore loss and dilution to the resource model at both green field sites and operating mines. For green field sites, multiple examples of benchmarks, deposit types, and mining methods are discussed to provide guidance for applying dilution and ore loss. At an operating mine, dilution and ore loss is adjusted using the results of a reconciliation program. Mines with a good reconciliation program along the full value chain are able to effectively account for ore loss and dilution within the resource model. Reconciliation at an operating mine along the full value chain is discussed with examples provided.

**2:45 PM**

## **A Site's Perspective on Global Standardization of Reconciliation Reporting**

*J. Rahn; Newmont, Elko, NV*

In 2013 Newmont Mining Corporation's North American sites started following a global reconciliation standard. Reconciliation reports are now issued by each site globally on a monthly basis and track several performance indicators on a monthly, rolling 3-month, and rolling 12-month window. This paper will present an overview of the performance indicators as well as discuss the challenges and benefits experienced at the Exodus mine site in complying with a global standard.

**3:05 PM**

15-119

## **Reconciling Mine Plans with Mine Operations at Freeport-McMoRan Sierrita**

*R. Vivas<sup>1</sup> and J. Garcia<sup>2</sup>; <sup>1</sup>Technical Services, Mintec, Tucson, AZ and <sup>2</sup>Long Range Planning, Freeport-McMoRan, Green Valley, AZ*

The creation of mine plans and the continuous supervision of their implementation go hand in hand. Ensuring the operation stays on target is vital so mine productivity and profitability can attain its maximum potential. Sometimes mine plans are not achieved, and the operation fails to meet its target which is a common issue revealed through reconciliation reports. This technical session discusses the methodologies and procedures used at Sierrita to monitor the implementation of the mine plans, measure the performance of the operation and reduce the variance between plan and actual in reconciliation reports.

## Mining & Exploration: Technology: Stope Design Technologies

**2:00 PM • Monday, February 16 • 708**

*Chairs: T. Dyer, Mine Development Associates, Reno, NV  
E. Peralta, MDA, Reno, NV*

**2:00 PM**

### **Introductions**

**2:05 PM**

### **Stope Optimizer/MSO – from Research Breakthrough to Industry Applications**

*H. Wang<sup>1</sup> and C. Alford<sup>2</sup>; <sup>1</sup>Newmont Mining Co., Greenwood Village, CO and <sup>2</sup>Alford Mining System, Melbourne, VIC, Australia*

Most underground mine designs were manual and very time-consuming. Compared to open pit mines that can be optimized using standard algorithm and commercially software for many decades, no such optimization tools were available for underground mines until recent years. PRIMO (Planning and Rapid Integrated Mine Optimization) was a global consortium research project sponsored by Newmont and other major mining companies and software vendors with the goal to develop an integrated set of mine design and schedule tools for underground mining engineers. Stope Optimizer, also known as Movable Shape Optimizer (MSO), was one of the few products came out of the PRIMO program and been commercialized. With a rapid and automated underground stope design algorithms, MSO has been imbedded with some of the general mine plan software packages, and been used by more and more mining companies and consultants. With continuous improvement of the algorithm and updated MSO versions, this design tool not only saves time and increases accuracy, but also enables engineers to improve some of the key value-adding elements of their work, such as cut-off grade strategy and mine option and scenario analysis.

**2:25 PM**

### **The Evolution of Stope Optimisation Technique in Three Decades**

*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 has 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 5 years. The goal of this research has been to automate the generation of stope shapes that honour the design requirements and are also rapid, repeatable and optimal. The focus has been to produce stope inventories suitable for strategic and tactical mine planning, and

progress towards automated shapes for operational planning. A variety of global and local shape optimization techniques are employed. 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.

**2:45 PM**

15-063

## **Case Study – UG Stope Optimization in Agnico Eagle’s Kittilä Mine, Finland**

*K. Huttu; Agnico Eagle Finland, Kittilä Mine, Kittilä, Finland*

The Kittilä underground mine is extracting one of the largest known gold deposits in Europe and has an estimated mine life through 2034. The Kittilä mine is located in the Lapland region of northern Finland. The ore at the Kittilä mine is refractory. The orebody consists of a complex pinch-and-swell structure including up to 100 different gold mineralization lenses. Fluctuating gold prices and other economic considerations increase the need to maintain and update the mining plans more frequently. Over 3,000 stopes need to be designed and optimized once a year for the LOM-plan and more frequent updates are needed for mid- and short term plans as well as production studies. As a large part of ore body is very sensitive to cost and gold price changes, stope optimization is crucial to find the best possible production scenario for every moment. Kittilä has gone through several methods for stope design and optimization. Most recently the Deswik Stope Optimizer (DSO) has been successfully used. DSO has helped Kittilä to design and optimize stopes in a timely and cost efficient manner. Together with the Deswik suite of planning tools, reliable and auditable plans are created.

**3:05 PM**

## **Conceptual Level Underground Evaluation of a Massive Sulfide Ore Deposit - A Case Study**

*J. Lonergan and A. Moharana; Client Services-Consulting, Mintec Inc., Tucson, AZ*

This paper will describe how MineSight® software was used to identify economic stoping boundaries, create minable stopes within the economic boundaries and schedule the stopes under different scenarios in a conceptual level analysis of the underground profitability (NPV) potential of the deposit. The deposit was previously mined by open pit methods and the owners were interested in the underground mining potential of the remaining resource. The remaining portion of the deposit being investigated measured approximately 1200m along strike, 700m down-dip, and 20 to 140m thick. Average dip of the deposit is 40 degrees. The determination of the economic stoping boundary was done assuming a sublevel long-hole stoping method with backfill. Stopes within the economic boundary were sized assuming a 30m nominal height. The stopes were scheduled based on different extraction rate, ore loss and dilution parameters. All work is done on a block model level of detail. This paper will describe the methodology used and the results of the evaluation.

**3:25 PM**

## **The Not So Quick and Dirty (NSQD) Method of Design Stopes**

*E. Peralta; MDA, Reno, NV*

Underground mine design is an iterative and complex process involving many inter-dependent parameters. Current software and technology is helping to decide how a deposit could or should be mined. In this decision making, mining software easily displays deposit geometry, length, height, and thickness, which along with engineering, economic and geotechnical input, all of which will determine the extents and the shape of the mining areas. Unlike open-pit mine design, underground mine design is mostly manual and a tedious process where engineers spend long hours drawing simple geometries that represent the mining shapes or stopes. This presentation discusses a method used by Mine Development Associates to quickly determine potential mining extents and or stoping areas for an underground operation. The methodology develops iterations from which economics can be analyzed including allocation of development cost and or preliminary schedules. The potential mining extents and or stoping areas can then be quickly redone to adjust to modified mining geometries prior to the final designs.

## **Mining & Exploration: Technology: Underground Mining Projects & Innovation I**

**2:00 PM • Monday, February 16 • 704**

*Chair: A. Nieto, Penn State University, University Park, PA*

**2:00 PM**

## **Introductions**

**2:05 PM**

## **Applying Optimized Underground Production Schedules in the Real World**

*A. Brickey; Mining Engineering, Colorado School of Mines, Golden, CO*

Open pit mine production scheduling has advanced since the 1960's, while its underground counterpart is still relegated primarily to manual scheduling methods. We present the application of an underground production schedule optimization model at an operating mine. We discuss the application of the schedule and the flexibility built into the model that accommodate the needs of the operation. The results are compared with traditional scheduling methods.

2:25 PM

15-054

## Longhole stope Mining – Mass Blast Project Phase 2 (Training and Implementation)

*S. Dereski<sup>1</sup>, S. Piercey<sup>2</sup>, G. Chancellor<sup>1</sup> and D. Durfee<sup>3</sup>;  
<sup>1</sup>Technical Services, Barrick Goldstrike, Elko, NV; <sup>2</sup>Mining Services, Orica, Sudbury, ON, Canada and <sup>3</sup>Technical Services Engineer, Southwest Energy, Elko, NV*

Barrick Goldstrike's Underground Division utilizes long hole stoping. The long hole stoping method consists of both primary and secondary stopes. Secondary stopes are typical surrounded by either cemented rock fill or paste fill. Original stoping method Drill entire stope, blast a bottom shot of the slot, blast the pull through (remainder of slot). Then series of production blasts to complete the stope. Between blasts material is mucked out and unblasted holes often have to be cleaned. Mass blast method Drill entire stope – moving slot closer to the footwall. Preform QAQC on stope,blast the entire stope at once. With the mass blast all the mucking is done after the single blast is completed. With the movement of the slot there is an increase of material at the front of the stope. This project was a collaboration between Barrick Goldstrike, Orica and South West Energy and part of the Value in Use Program, a global agreement between Orica Mining Services and Barrick Gold. This paper focuses on the mass blast project implementation and the steps taken to advance the project from a consultant and engineering-driven study to standard practice.

2:45 PM

15-131

## Innovative rehabilitation of existing tunnels under minimum impact on operation

*A. Nitschke<sup>1</sup>, J. Dase<sup>2</sup>, I. Ossenbühl<sup>3</sup> and W. Dolsak<sup>4</sup>; <sup>1</sup>Gall Zeidler Consultants, Ashburn, VA; <sup>2</sup>Rio Tinto Kennecott Utah Copper, South Jordan, UT; <sup>3</sup>Beton- und Monierbau GmbH, Herten, Germany and <sup>4</sup>DSI Underground Systems, Inc., West Jordan, UT*

The authors have successfully developed and innovative rehabilitation concept, which meets actual technical standards and minimized the impact on operation of a key conveyor tunnel. The flexible and stepwise ground support rehabilitation program utilized a combination of yielding steel arch sections with groutable Bullflex hoses, a fast and safe backfilling support system. The system was developed and successfully installed at Bingham Canyon Mine, the world's largest open pit copper mine, which also includes numerous underground structures. The mine is owned and operated by Kennecott Utah Copper mining operation of Rio Tinto. The system was implemented at a conveyance tunnel, which was originally designed as a railroad tunnel, but was re-commissioned and is currently used as a conveyor belt tunnel to transport ore from the open pit to processing facilities outside the mine. The existing structure showed signs of overstressing due to movements in the surrounding rock mass, which had to be addressed with a yielding support system to provide safe access into the tunnel. However, the impact on the conveyor belt operation due to support installation was to be limited to the bare minimum.

**3:05 PM**

## **uGPS: Developing a mobile localization and 3D mapping technology for the underground mining industry**

*A. Chapman and J. Lavigne; Peck Tech Consulting Ltd., Montreal, QC, Canada*

While the surface mining industry was greatly advanced with the introduction of global positioning systems (GPS) in the 1990s, no comparable technology yet exists underground. Similarly, 3D mapping underground is an emerging field but so far has been constrained to conventional, stationary surveying set-ups. This paper covers the authors' work in developing a mobile underground positioning and mapping technology for the mining industry. This LIDAR-based approach has succeeded in its original goal of mine site-wide positioning with precision comparable to surface L1 GPS, and as a necessity has evolved an impressive capability for rapid volumetric mapping. The process of commercializing this technology from the initial research stage to the finished product is reviewed, including technical challenges, input from industrial partners, and results from real world use cases. Also highlighted are capabilities of the finished product's technology platform, and a few applications of the technology with the potential to revolutionize underground planning and production operations.

**3:25 PM**

## **Development of Road Header Roof Bolting Module**

*S. Farrell; Industrial Minerals, J. H. Fletcher & Co., Huntington, WV*

In underground mining, machine design is predominantly dictated by mine conditions and individual customer desires. J. H. Fletcher & Company was tasked to design and manufacture a set of extending roof bolting modules to be mounted on either side of a roadheader providing in-cycle bolting. The result of the design is a multistage boom with over 24 feet (7.31 m) of extension. The bolt module builds on previous designs and incorporates a modular assembly with each sub-component designed to be replaceable and adjustable independent of other machine components. Each major component is painted a different color to help the operator make the connection visually from the module to the operator's control valves. This design removes the operator from working in unsupported roof and away from inherent hazards. By combining the cutting and bolting equipment onto one machine, the unused availability in separate machines has been eliminated. The hydraulic package valves eliminate the need for any electronics, thus avoiding any electrical regulations and simplifying the controls. The modules increase miner safety and streamline production.

**3:45 PM**

15-062

## **In-situ Underground Bioleaching - Novel Conditioning Technologies**

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

The “Biohydrometallurgical Center for Strategic Elements (BHMZ)” is a cooperation of 13 departments of the Technical University Bergakademie Freiberg fostering interdisciplinary research along the whole (bio-)hydrometallurgical process chain to extract indium and germanium from sulphide ores. Research comprises methods to (i) bring the respective metal from the source material into aqueous solution and (ii) different approaches to extract pure metal or metal-containing materials from the solution. Within the BHMZ the Department of Underground Mining Methods deals with the design and implementation of a underground testing facility for microbial in-situ stope leaching in its own “Research and Educational Mine”. The intention is to investigate innovative approaches for leaching technologies by crack initiation due to hydraulic fracturing or water pressure blasting under consideration of leaching kinetics and underground conditions. It is planned to set up two testing units comparing energy input and the metal output of conventional (blasting) as well as one of the innovative technologies. Aim of subproject is to establish an innovative and sustainable method ready for up-scaling.

## **Mining & Exploration: Technology: Utilizing Simulators for Mine Equipment Training**

**2:00 PM • Monday, February 16 • 703**

*Chair: D. Rosenbach, Atlas Copco, Commerce City, CO*

**2:00 PM**

## **Introductions**

**2:05 PM**

## **Development of first Autonomous Hauling System Training Program and Simulator**

*J. Humphrey and R. Pool; Caterpillar, Decatur, IL*

The author developed the initial training program for the Command for Hauling autonomous truck operating staff. He will relate lessons learned, specifically the application of a custom state of the art simulation system. This ground breaking work enabled an unprecedented rapid deployment of multiple sites around the world, including the worlds largest autonomous haulage site.

**2:25 PM**

## **The Evolution of the Simulator and its Impact on the Industry**

*S. Perry; CAE Mining, Denver, CO*

As a training tool, simulators provide a safe and effective environment for operator trainees to confidently increase their skills on a particular machine. Simulators have been used for decades in many industries and have helped to standardize operating procedures that yield greater safety and productivity. Simulators are available in different levels of fidelity and capability and the best results are achieved when the right type of simulator is deployed to accomplish the objective(s) it is designed to support. The mining industry has seen dramatic growth in suppliers of equipment simulation due to mining companies looking for options to train operators more efficiently. The industry OEM's, gaming companies, and companies focused on simulation and training have all worked to develop tools to satisfy the demand of mine operator trainers. The results have been mixed due to a lack of regulations or structured certifications in the industry, and simulation development has not yet consistently delivered the results seen in other industries where guidelines have been put in place to drive how simulators are designed, developed and deployed to maximize operator performance in the field.

**2:45 PM**

## **Simulator Applications Today**

*L. Lajoie; CAE Mining, Montreal, QC, Canada*

Simulators today are most often used as a bridge between the classroom and in-field training. Most companies look to a simulator as a way to embrace innovative technologies that enable them to reduce costs and safely increase productivity. Reduction of costly maintenance incidents that can result during training activities, increased availability for production, and ensuring that the training environment contributes to the safe operation of the mining equipment are many advantages of using simulators. In today's market, simulators range from basic computer-based learning activities to advanced equipment simulators that replicate the machine operations. These advanced simulators operate in high-fidelity environments designed to mimic how a vehicle would function in an actual mine setting. As with different adult learning styles, no one simulator type is optimal for every application. Price, usage and expected outcomes are key criteria to consider when choosing what level of simulation to incorporate to a training program. While simulators are already delivering value to the mining industry, so much more can be achieved by fully understanding the capabilities of these advanced tools.

**3:05 PM**

## **Where the Use of Simulators are Going**

*S. Mercier; CAE Mining, Montreal, QC, Canada*

The mining industry faces increasing challenges from a number of areas: global economic cycles, extracting ore from more complex environments, and incorporating increasing regulatory requirements in how they operate profitably. Simulation technology provides mining operations with resources to optimize how

they address these challenges. As more companies focus on operational excellence to ensure current practices and workforces are efficient, training with simulators will play a key role in the coming years. One area in which training will evolve is in teaching mine crews in the same simulated environment to work together. As military applications of “mission training” in simulators has demonstrated, crews will be able to learn how their actions impact the actions of others and how they can better coordinate their actions to optimize safety and productivity. As in other industries, regulations have driven the development of simulator capabilities. There is also a growing demand for mining remotely and simulators will play a role in how these mines operate equipment and facilities from great distances.

**3:25 PM**

## **Why Simulators Fail and How to Make Sure They Don't**

*S. Perry<sup>1</sup>, L. Lajoie<sup>2</sup> and S. Mercier<sup>2</sup>; <sup>1</sup>CAE Mining, Dever, CO and <sup>2</sup>CAE Mining, Monreal, QC, Canada*

The root causes for most failed simulator investments can be attributed to one or more of the following: wrong diagnosis of the actual needs, lack of expertise in instructional design, lack of expertise in training using high-tech tools, workforce perception of the simulator as a gadget or toy, poor planning and implementation on how to incorporate the simulator into a training program, lack of alignment between the training professionals and the operations leadership, lack of well-defined training programs, and poor choice of tools based on expected outcomes for these devices in the training deployment. In order to increase the probability for success, mining management must learn to properly define what the training program will deliver and what resources are required to succeed, it must learn how to structure a blended-learning/training and evidence-based approach to demonstrate tangible results for all stakeholders, how to work with operations to align continuous assessment with fleet management and training analytics to ensure operator sustained and reliable performance, and how to implement evidence reporting to substantiate return on investment for training activities.

## **My First Five Years in Operations**

**2:00 PM • Monday, February 16 • 711**

*Chairs: M. Sloan<sup>1</sup>, Arch Coal, Pennington Gap, VA  
R. Wagner<sup>2</sup>, PBS Coals, Inc., Somerset, PA*

**2:00 PM**

## **Introductions**

2:05 PM

## Mine Operations & Human Performance Improvement

*J. Salomon; Operations, Luminant Mining Company, Fairfield, TX*

Over a period of several years I went from technical professional in mine engineering (metal, non-metal, and coal) to management of the operations department of a large surface coal mine. Through this time I struggled to meld technical knowhow into practical application and execution until I discovered Human Performance Improvement (HPI). HPI is a workplace culture which is derived from a philosophy which guides management decisions by understanding that all people make errors and that management systems can affect the frequency and severity of those errors. Utilizing HPI and having a constant drive to apply the principals leads to advances in safety, production, and cost control.

2:25 PM

## Professional Development: The learning transition

*R. Rojas; Resource Management, FreeportMcMoran Cu & Au Inc., Morenci, AZ*

This paper is intended to provide the audience with some tools to develop their career path. The suggested process has five different stages: (i)find the right mentors to understand the business from different perspectives; (ii)work on research and development; (iii)build a professional network, and learn from them;(iv) apply new learned concepts at work ;(v) share your knowledge within your colleagues, get them on board. It is critical to consider the tools mining engineers(MEs) need to learn on this path, most of them, you haven't learned at your time in college. Develop your analysis capabilities, provide a fast response to unexpected situations, provide new insights, provide strategic information for real time decisions and manifest those results into a better control of the operation and costs. MEs often involve international travel for what adaptability skills will be required to adjust to a new culture, new language among other variables that come into account for your success. To work on developing people's skills may have an enormous impact for the future generations in mining and assure its sustainable development, be encouraged to do so within the team you belong to.

2:45 PM

## From College Graduate to Coal Mine Engineer – Practical Engineering Experiences

*B. Ashley; Engineering, Rosebud Mining Company, Kittanning, PA*

The tassel was turned and diploma received, then off I went to the real world of mining engineering. Five years ago, I graduated with my B.S. in Mining Engineering from The Pennsylvania State University. My first job awaited me at Rosebud Mining Company, conveniently located in my hometown of Kittanning, PA. Rosebud Mining Company specializes primarily in shallow (<600 ft of cover) low-seam (<5 ft thick) underground coal ex-

traction. For the past five years, I have worked in Rosebud's engineering department as a mining engineer. From engineering assistance of day-to-day underground operations to long-term planning, I have accumulated countless practical mining engineering experiences. Some such experiences include: ventilation analyses, pillar design, geotechnical analyses, stripping ratio calculations, underground construction, surface site and structure design, power supply, railroad layout, and horizontal drilling. I also learned that not only must an engineer be proficient in design, but one must also be an effective communicator – communicating with fellow engineers, geologists, management, contractors, government agencies, and most importantly, the miners themselves.

**3:05 PM**

## **Recognizing Open Doors – Diversifying My Skillset to Accomplish a Singular Goal**

*T. Rauch; Jacobs, Calgary, AB, Canada*

Starting with a broad-based industry focused college education, Thomas has transitioned through heavy industry while being challenged with a steep learning curve and a desire to perform. Discussing professional development as a young professional, international exposure, constricting markets, acquisitions, and changing firms, Thomas shares his experiences to highlight lessons learned, development practices, and the value of mentors. Further focus is given to key skillsets that translate well from role to role including data science, technical writing, and commodity market economics. Targeting the benefit of young SME members as well as insight for developing and retaining young professionals in the mining industry, the presentation travels a chronology of projects and roles with an emphasis on visual presentation.

**3:25 PM**

## **The Importance of Your First Job Selection**

*M. Furniss; PBS Coals, Inc, Friedens, PA*

When entering the workforce after graduation it is important to understand the importance of the first job. There are many paths that one can take including industry engineering, industry operations, consulting engineering, sales, and government/research. Although it is possible to move between these areas it is often challenging if there is no overlap in experience. The aspiring mining professional should take strides to research potential career paths that can stem from each opportunity they are evaluating prior to selection.

**3:45 PM**

## **Finding a Career, Not Just a Job**

*J. Whitney; Mining Engineering, Lehigh Hanson, Irving, TX*

As students set out to leave their college days behind and embark into the mining industry it is important that they locate a career and not just a job. A job will pay the bills but a career will be a rewarding endeavor which provides challenges and rewards along the path to the individual's goal occupation. Students need to ask appropriate questions of themselves be-

fore interviewing, such as “What is my goal occupation?” and “Do I know what it takes to achieve my goal occupation?”. Students also need to ask appropriate questions to interviewers such as “What is the career path you can offer me?” and “What will be needed for me to advance within the company to a plant manager or head of engineering?”. In addition, new employees in the mining industry must not become complacent. Instead, they should ask themselves at least yearly “Is the role I am in currently providing me adequate training to advance my career?” and “Am I doing enough in my current role to show my supervisors that I am capable of taking on new challenges and responsibilities?”.

## **Research: Focus on Innovation in Mining Industry**

**2:00 PM • Monday, February 16 • 507**

*Chairs: E. Fretheim, Freeport-McMoRan, Oro Valley, AZ  
A. Samal, Rio Tinto Exploration, Riverton, UT*

**2:00 PM**

### **Introductions**

**2:05 PM**

### **Integrating Collision Avoidance Technology with Fatigue Monitoring – A Case Study**

*T. Ruff; SAFEmine Technology USA, Oakland, CA*

Visibility limitations from the cab of surface mining equipment are a contributing factor in many of the collisions with smaller vehicles, workers on foot, or other machines. Collision avoidance and traffic awareness systems are available that can help prevent these collisions and the trend is toward the integration of multiple technologies to offer comprehensive protection. For example, operator fatigue can also play a role in collisions and other vehicle-related incidents. By combining collision avoidance with fatigue monitoring technology, the effectiveness of each system in helping to prevent a wide range of incidents can be improved. SAFEmine has developed an integrated solution that combines data from the Collision Avoidance System, such as vehicle motion and operator reaction to traffic, with fatigue monitoring technology that uses a combination of PERCLOS and other assessment methods. The result is a fatigue monitoring system that provides in-cab alerts with less nuisance alarms along with predictive analysis for a preventative approach. A description of this technology and data from a pilot study at a mine site is presented.

**2:20 PM**

### **Selecting Next-Gen Networking Technology**

*K. Byles; Rajant Corporation, Malvern, PA*

With so many wireless technologies to choose from, how do you know what is best for your deployment? Whether it is Point-to-Point, Point-to-Multipoint, or Mesh, it can be challenging to make an educated decision on what is best for your application.

Most of these topologies can be deployed in a variety of applications which can make the decision even harder. To make the best choice, you need to first have a solid technical understanding of these wireless technologies and how they should be deployed to best serve the customer and to enhance connectivity. In each of these configurations, you can find very low frequency to high frequency products in both the licensed and unlicensed brands. This creates the challenge of finding most capable product for your deployment. In this session, we will give an overview of how to differentiate between the different networking topologies and the inherent advantages and disadvantages of each. Then, we will discuss the applications for each of them. Finally, we will discuss best practices for evaluating your organizational needs, and what types of wireless technologies are necessary for different aspects/locations of your deployment.

**2:35 PM**

15-078

## **Underground experimental mines for technology and mining equipment research and development**

*H. Mischo; Mining Engineering, Technical University Bergakademie Freiberg, Freiberg, Germany*

On-site research and development as well as in-situ testing are key factors to the successful implementation of new mining equipment and technology. Unfortunately the demands and necessities of research and development often conflict with the reality of mine production in operational mines, especially during early stages of research and development and the initial testing of new equipment. Several experimental mines under university supervision attend to this problem and provide a close-to-reality testing environment for the mining industry and mining equipment manufacturers. This paper gives an overview of the design and organisation of such an underground testing area as well as of the wide range of possible operations it can facilitate at the example of the FLB Experimental and Teaching Mine (Forschungs- und Lehrbergwerk) at Technische Universität Bergakademie Freiberg, the central European underground research mine.

**2:50 PM**

15-069

## **Synthetic Fibre Ropes in Haulage Systems in Underground Mining**

*H. Mischo and A. Dietze; Mining Engineering, Technical University Bergakademie Freiberg, Freiberg, Germany*

Mining activities, especially underground mining operations, create great demands on utilised haulage means which cover a number of different horizontal and vertical distances. In the course of the continuous optimisation of the haulage process, the application of textile machine elements, in particular synthetic fibre ropes, offers new opportunities. Therefore the current level of knowledge needs to be improved based on extensive analyses. For the estimation of the scope of these analyses, various fields of application and occurring environmental influences which have an impact on synthetic fibre ropes during

their use in underground mining have to be evaluated. The Chair Underground Mining Methods of the TU Bergakademie Freiberg works on a scientific project concerning the use of synthetic fibre ropes in underground mining operations. This paper focuses on the potential application of synthetic fibre ropes in haulage systems in underground mining and exposes critical influences as an outcome of the working environment. These first investigations are the basis for the development of an appropriate experimental series.

**3:05 PM**

## **Elemental Analysis of just about everything using an energy dispersive XRF with a camera**

*W. Lipps; Shimadzu Scientific Instruments, Columbia, MD*

A whole rock analysis used to involve collecting a specimen, grinding it up, dissolving it, and making numerous wet chemical or instrumental determinations to obtain elemental concentrations. Mineral identification required cutting of thin sections for microscopic analysis or pulling individual grains for X-Ray diffraction. Now, determining the elemental composition and relative concentration of major and minor elements in hand specimens is easy using an Energy Dispersive XRF with a large sample chamber and a CCD camera for accurate "aiming" of the X-Ray beam. This presentation shows examples of individual sulfide and oxide ore minerals contained in various hand specimens analyzed and photographed by an XRF Analyzer.

**3:20 PM**

**15-123**

## **Ultra-wide-band technology for high precision ranging applications**

*J. Berg, K. Neumann, M. Zingsheim and K. Nienhaus; Institute for Mining and Metallurgical Machinery, RWTH Aachen University, Aachen, Germany*

Automation tasks in mining processes are various like the mining industry itself. Research and development has shown interest in the ultra-wide-band technology (UWB) in recent years. While short range, high speed data transfer is the current main research focus, the technology can also be used for high accuracy ranging applications. Since UWB based ranging is robust against typical disturbances in mining environments (EMC, rain, dust etc.), it is attractive for use in mining applications. The Institute for Mining and Metallurgical Machinery (IMR) at RWTH Aachen University, has evaluated the technology in several use cases. Besides one- and multidimensional laboratory measurements, multiple field tests in both underground and open pit scenarios were conducted. The paper discusses test results of these tests focusing on accuracy, achievable range and general applicability, as well as its feasibility for mobile machine tracking and positioning.

**3:35 PM**

## **Digitally Controlled Water Distribution for Open Pit Mining based on Ground Speed with Geo Zone control, data logging, and remote communication**

*E. Motes; Business development, Open Loop Energy, Inc, Safford, AZ*

In Open Pit Mining the water truck is a vital component of production. They are responsible for dust control and are used for road maintenance. Managing the water, and other fluids dispensed is critical to mine management. Through new industry technology a proven method has been developed using digital controlled DCM systems. This revolutionary system precisely manages water distribution for large mining water trucks based on ground speed. This technology has been further developed to enable the user to data log the spray pattern, water flow and location as well as remotely communicate this information back to operations to be used in mine planning and production. This technology provides real time information as to how the water trucks are being utilized. Attendees to this session will learn: How mining companies can effectively control distance, density, and flow rates as never before seen on mine water trucks. Learn how this technology offers a solution to the problems of “over watering” or “under watering” mine terrain. Learn how Geo Zones have been utilized in water truck operations at mine locations. Learn what reports can be generated.

**3:50 PM**

## **The Case for Innovation in the Mining Industry**

*P. Bryant; Kellogg Innovation Network, Kellogg School of Management, Evanston, IL*

The case for innovation has never been more compelling: we are facing a sharp dip in what remains to be the largest mining super cycle not seen since the WWII. But there are severe headwinds - escalating operating costs; escalating capex; declining grades; \$25bn of projects on hold due to community or govt issues; declining productivity - efficiency alone will not resolve - transformation innovation has never been more important. A return to acceptable returns demands companies to realize important transformations in their business system: rapid and accurate characterization of ore bodies, faster development of mines and speed of extraction, improved recovery rates and mine planning as well as increased use of automation and remote operations and ultimately an entirely new production platform. The Mine of the Future is the transformational paradigm that acts as the focus for this innovation. This session will examine the forces shaping the industry, current state of technology and innovation in the mining industry and highlights the internal and external factors that have under-mined innovation efforts and look at the opportunity posed by technology from an adjacent industry.

4:05 PM

15-125

## **Wearable Technology for Critical Notifications in Mining**

*E. Chow; Motion Metrics International, Vancouver, BC, Canada*

While Wearable Technology has been garnering attention in the consumer market, enterprise and industry have just begun exploring its potential applications. Since February 2014, Motion Metrics International has been working in collaboration with Vandrico Solutions Inc. to apply Wearable Technology to improve productivity and safety in the mining industry. This paper discusses the value proposition of using Wearable Technology to deliver critical notifications in mining. The advantages and disadvantages of various form factors are explored. The challenges, both specific to mining and in general to Wearable Technology, are defined. Finally, the concept of MetricsGear™, a smartwatch under development by Motion Metrics International in collaboration with Vandrico Solutions Inc., is described. MetricsGear™ is designed to notify the user with minimal distraction to keep the user focused on their primary task, and aware of mission-critical events. This focus and awareness allows the user to work more efficiently and safely.

Tuesday, February 17

Morning

**Bulk Material Handling: Improvements in Conveyor Maintenance and Safety****9:00 AM • Tuesday, February 17 • 709**Chair: **D. Bailey**, CONetic Resources**9:00 AM****Introductions****9:05 AM**

15-120

**Sealed Spherical Roller Bearings used on Conveyors Improves Production***J. Cleason<sup>1</sup> and J. Oliver<sup>2</sup>; <sup>1</sup>Regional Sales and Service, SKF USA, Salt Lake City, UT and <sup>2</sup>Engineering, SKF USA, Lansdale, PA*

With Maintenance costs rising and an increasing demand for higher production, the use of sealed spherical roller bearings can reduce maintenance costs while providing increased production. The sealed spherical roller bearing has increased bearing life by slowing the ingress of contamination. This paper will describe how contamination and bearing wear is reduced by reviewing case histories from coal and metal mines that have improved their production by decreasing down time using sealed spherical roller bearings.

**9:25 AM**

15-135

**Automatic Lubrication in Mining Applications Improve Reliability and Decrease Maintenance Costs***K. Bommer<sup>1</sup> and M. Hawkins<sup>2</sup>; <sup>1</sup>Applications Engineer, SKF, Elgin, IL and <sup>2</sup>Industry Specialist, SKF USA, Scottsdale, AZ*

In today's fast paced globally competitive world, reliability and machine uptime are of the utmost importance to insuring a successful operation. Along with these targets more emphasis is being put on cost reduction and decreasing environmental impact of the overall system. Automatic lubricators and lubrication systems have been used in many industries for years to achieve all of these goals and are now becoming a common tool in the mining industry as well. These systems are able to provide proper lubrication amounts at the proper times autonomously, helping to keep the machines running smoothly while minimizing the physical support required. Copper mines in the southwest have begun utilizing auto lubrication to avoid mistakes and unplanned shut downs on critical equipment. This paper will describe the engineering behind these products and review case histories where these tools have been successfully utilized in the mining industry.

**9:45 AM**

15-038

**Conveyor Design for Safety and Maintenance***R. Swinderman; RToddS Engineering, LLC, Palm Coast, FL*

This paper will discuss the topics in CEMA's recently released 7th edition of Belt Conveyors for Bulk Materials that deal with safety and maintenance. There are some topics from the 6th edition that carried over to the 7th edition that are important for safety and maintenance such as CEMA's recommended clearances around conveyors discussed in Chapter 2. There are several key differences in the 7th edition compared to previous editions that are focused on safety. CEMA has included a risk analysis method arranged specifically for bulk material handling conveyor and systems. One unique aspects of CEMA's risk analysis is a list of potential hazards relevant to conveyors. In the 7th edition there is a section on determining maintenance staffing and recommended routine inspection and maintenance activities that are designed to help maintenance managers justify adequate staffing.

**10:05 AM****Impact of Fuel Sources in off Highway Vehicles***J. Mazumdar; Siemens, Alpharetta, GA*

Safety and Sustainability along with a push to increase productivity are the trends seen in equipment operating in open pit mines. An area of improvement has been the implementation of Trolley Assists for operating haul trucks. Rising fuel prices, greater environmental awareness and the fuel consumption has led to renewed interest in Trolley Assists. Several mines have implemented this technology and significant improvement in productivity and fuel efficiency has been realized. In addition, a trolley guidance system has been developed which assists the truck operator to keep the truck in the right position under the overhead line. Field tests have been completed successfully with satisfactory results. Historically, Diesel has been the fuel of choice for mining trucks. In recent times, LNG has emerged as an alternative fuel for powering mining trucks. LNG has some unique features like lightweight, narrow flammability range, does not detonate in open atmosphere and high volumetric energy content that are desirable for mining truck operation. This paper will investigate the feasibility of using LNG in mining truck operations as well as review the benefits for such a transition.

**10:25 AM****The New CEMA 576 Belt Cleaning Standard (and What It Means to You)***D. Mueller and A. Marti; Corporate Marketing, Martin Engineering, Neponset, IL*

North America's Conveyor Equipment Manufacturers Association has released a new publication, CEMA No. 576, "Classification of Applications for Bulk Material Conveyor Belt Cleaning. This standard has been established to provide a uniform method for determining the application class of any in-

dividual belt conveyor. This application class will assist in the selection of an appropriate conveyor belt cleaner or conveyor belt cleaner system for the application. By ranking the application, a conveyor engineer or end-user has guidance concerning the needed ruggedness and durability needed in a conveyor belt cleaner for a given applications. In this presentation, a representative of one of the world's leading suppliers of belt cleaning systems, will look at this new system, walk audience members through the methodology, and discuss how to use, and how to improve the recommendations from its methodology

## **Coal & Energy: Coal Preparation II**

**9:00 AM • Tuesday, February 17 • 504**

*Chairs: B. Arnold<sup>1</sup>, Preptech, Inc., Apollo, PA*

*T. Ghosh<sup>2</sup>, University of Alaska Fairbanks, Fairbanks, AK*

**9:00 AM**

### **Introductions**

**9:05 AM**

15-117

### **Micro-Price Optimization: An Industrial Case Study for Coal Processing Facilities**

*G. Luttrell<sup>1</sup>, A. Noble<sup>2</sup> and F. Stanley<sup>3</sup>; <sup>1</sup>Mining & Minerals Engineering, Virginia Tech, Blacksburg, VA; <sup>2</sup>Department of Mining Engineering, West Virginia University, Morgantown, WV and <sup>3</sup>Private Consultant, Abingdon, VA*

Attempts to optimize the coal supply chain have historically been difficult due to the lack of coordination between the various groups involved in coal production, transportation and utilization. In light of this issue, a new approach called Micro-Price Optimization has been developed to simplify the optimization problem and to provide coal producers with fundamental insight needed to improve profitability. According to this concept, optimization occurs whenever the maximum tonnage of positive value particles and minimum tonnage of negative value particles are recovered and passed to market. Factors considered by the concept include coal washability, target boiler cost/efficiency, waste disposal costs, quality values, emission penalties, transportation charges, or any other quantifiable impact factor. This article reviews the Micro-Price concept and provides a detailed industrial case study involving the identification of optimum coal qualities supplied to a coal-fired power station.

**9:25 AM**

15-080

## **Micro-Pricing Optimization: Value-Based Partition Curve Analysis with Applications to Coal Separation**

*A. Noble<sup>1</sup> and G. Luttrell<sup>2</sup>; <sup>1</sup>Mining Engineering, West Virginia University, Morgantown, WV and <sup>2</sup>Mining and Minerals Engineering, Virginia Tech, Blacksburg, VA*

In coal and mineral processing, several numeric parameters are used to quantify the separation performance of unit operations. For density-based separations, the partition curve is used as the starting point for many stages of diagnostic analyses. The curve is often quantified by its midpoint slope sharpness, and this single value is subsequently used for technical evaluation, benchmarking, and comparison. While this analytical approach does depict misplacement by gravity class, it inherently prioritizes middling separation and does not consider process economics or the micro-price value of individual classes. Alternatively, the organic efficiency parameter does consider process economics; however, it does not reveal information on the root cause of lost revenue or misplacement. In this paper, a new analytical approach is introduced which reconciles the technical misplacement data derived from the partition curve with the economic data derived from micro-pricing. The result is a new analytical procedure which reflects a better use of performance data.

**9:45 AM**

## **Development of Operating Guidelines for Desulfurization Spirals in Flotation Circuits**

*R. Bratton<sup>1</sup>, G. Luttrell<sup>1</sup>, M. Mohanty<sup>2</sup>, L. Ackah<sup>2</sup> and F. Farbaksh<sup>2</sup>; <sup>1</sup>Mining and Minerals Engineering, Virginia Tech, Blacksburg, VA and <sup>2</sup>Mining and Mineral Resources Engineering, Southern Illinois University Carbondale, Carbondale, IL*

Previous studies have indicated that density-based separations are effective in reducing sulfur due to the large density difference between pyrite and coal. On the other hand, the data also showed that sulfur rejections obtained in froth flotation are often poor due to pyrite floatability. Further analyses indicated that the preferential partitioning of pyrite to the underflow streams of classifying cyclones and fine wire sieves could be exploited to concentrate pyrite into low-volume streams that could be effectively treated using desulfurization spirals. Unfortunately, design parameters and operating guidelines for spirals in such applications are currently unavailable. To this end, a series of in-plant evaluations were conducted at an Illinois coal preparation plant using a full-scale spiral to determine the optimum operating conditions for desulfurizing ultrafine (minus 100 mesh) flotation feeds. On the basis of this study, recommended design parameters and operating guides for flow rates, solids content, splitter settings, etc., are provided for incorporating desulfurization spirals in flotation circuits.

**Coal & Energy: Ground Control Case Studies****9:00 AM • Tuesday, February 17 • 503***Chair: S. Tadolini, Orica, Georgetown, OH***9:00 AM****Introductions****9:05 AM**

15-030

**Ground Observation System (GOS): a web-based data information center for ground control monitoring***W. Conrad, D. Westman, A. Russell and B. Thomas; Mining and Minerals Engineering, Virginia Tech, Blacksburg, VA*

Understanding ground control problems continues to remain a focus of the mining engineering community. To aid mine operators and engineers in identifying and responding to ground control issues, the Ground Observation System (GOS) is being developed. The GOS is an integrated, web-based graphical user interface that displays ground response data collected wirelessly from an underground mine. It presents data in an intuitive manner to assist mine personnel, who are on- or off-site, in quickly identifying hazardous areas. Geotechnical instrumentation will be connected to wireless transmitters that will relay data in real-time to a surface computer that stores the information in a database. The GOS website will then display the geotechnical data in graphical and tabular forms, as well as in a conditionally formatted mine map. Data from each measurement device will be able to be viewed in its entirety or within a time interval, and can be downloaded for further analysis. The ability of the GOS to quickly interpret and communicate mine hazards to personnel of varying technical ability should prove to be a useful tool in understanding ground control and thus improving mine safety.

**9:25 AM****Multiple-Seam Mining in the United States: An Analysis of Multiple Seam Stability in Northern Appalachian Coal Mines with Minimal Depth of Cover and Interburden***M. Castner; Rosebud Mining Company, Kittanning, PA*

Coal mining in the US has progressed and today there are more mines operating above or below previously mined out coal seams. Studies from 1981 estimated two-thirds of the minable coal reserves in the US would be impacted by multiple seam implications. Thus, it is obvious that most of the remaining mineable reserve will be influenced by extraction that has already occurred in seams located above and/or below current and future mining operations. To ensure the safety of their operations, mining companies are spending a growing amount of time and resources on understanding the implementations of multiple seam mining and the effects previously mined out seams have on current and future operations. One of the most valuable

engineering tools currently available is the AMSS program (created by Dr. Mark and NIOSH). Two critical parameters used in determining safety are: Depth of Cover and Interburden. This report provides a through synopsis of the history and impact that multiple seam mining has had on the mining industry while also providing some cases studies (depth of OB  $\leq$  500 ft and IB  $\leq$  150 ft) for northern Appalachia coal mines which will help strengthen the AMSS database.

**9:45 AM**

### **Numerical Model Calibration for Simulating St. Peter Sandstone Pillar and Roof Rock Response based on Field Measurements: A Case Study at Pattison Sand Mine, Clayton, Iowa, USA**

*F. Arthur, M. Ge, E. Gbadam and A. Bagherieh; Mining engineering, MissouriS&T, Rolla, MO*

St. Peter Sandstone formation is a unique material characterized by unusual high friction angle and almost cohesionless. This friable rock has posed a number of ground control challenges at Pattison Sand Mine located in Clayton, Iowa in the United States. In order to predict the state of its pillar stress and roof deformation, a numerical model is require calibrating the model results with measured field results. In this paper, a numerical model has been developed and simulated in a sequence similar to the field mining conditions. The models results compares very well with measured pillar stress and roof deformation measured in the field. The study reveals typical St. Peter Sandstone cohesion stress of 300 KPa, a value which is not reported in literature.

**10:05 AM**

### **The Characterization of Basic Strength Properties for the St. Peter Sandstone in Clayton, Iowa**

*A. Bagherieh, M. Ge and F. Arthur; Mining engineering, MissouriS&T, Rolla, MO*

St. Peter sandstone covers large area in North America. The interest for St. Peter sandstone has been increasing due to the upward trend for for fracking sand. This material is possesses very unique mechanical properties. On the one hand, it is brittle as characterized by an unusually high friction angle, up to 69°, and steeply curved failure envelopes. On the other hand, it is friable, and cohesionless. The goal of this research is to establish a fundamental understanding of the basic mechanical and strength properties of the St. Peter sandstone. The strength properties of the St. Peter sandstone were examined utilizing uniaxial test, triaxial test, porosity measurement, particle size distribution, and optical and scanning microscopy. Because of highly friable nature of St. Peter sandstone, conventional sample preparation techniques are difficult to apply for it. In this study, an appropriate sample preparation procedure for the St. Peter Sandstone was developed. The strength dependency of uniaxial compressive strength (size effect) was studied for this type of geological material. Rectangular cubic samples having nominal size of 2 in. were selected as the optimum size.

**Coal & Energy: Mining Research and Development****9:00 AM • Tuesday, February 17 • 501**

*Chairs: D. Alexander<sup>1</sup>, NIOSH, McMurray, PA  
A. Noble<sup>2</sup>, West Virginia University, Morgantown, WV*

**9:00 AM****Introductions****9:05 AM****A Design Tool for Improving Safety of Highwall Mining Operations**

*Y. Luo; Mining Engineering, West Virginia University, Morgantown, WV*

As a relatively new mining method, highwall mining is a preferred and often the only feasible method for extracting coal reserve left by surface mining operations in areas with steep terrain and in closely spaced thin coal seams. Though its safety record is comparable to that of surface mining, many failures of mine structures in highwall mines, especially the highwall, have occurred. The methods for systematically designing highwall mining operations to meet the safety and operational challenges are still evolving. A research is conducted to improve the existing and to develop new design methods for highwall mining operations. The design methodology is to ensure structural stability of the highwall, roof, web and barrier pillars and to prevent subsidence. Major ground control challenges of soft and layered mine roof, interactions from mining closely spaced coal seams are considered in the methodology. An optimization design process applying pressure arch concept can be incorporated to improve recovery ratio of coal reserve. A computer program based on the design methodology is developed. The paper will present the design methodology and application cases of the design program.

**9:23 AM****Mechanical Model for Estimate Energy Requirement and Noise Generation in Roof Bolt Drilling Operation**

*M. Li and Y. Luo; Mining Engineering, WVU, Morgantown, WV*

Hearing loss among roof bolter operators is a serious health issue. Noise generated in roof drilling contributes a major proportion to noise exposure to roof bolter operators. The previous experimental results show that rationalized drilling control can not only maintain a good drilling productivity but also significantly reduce noise level, noise dosage and required drilling energy. A rationalized drilling control is implemented through proper penetration and rotational rates according to rock strength, drill bit and steel used. However, it still lacks a good theoretical study on energy requirement and noise generation in the rock breakage process of rotary drilling which can provide a strong foundation for developing innovative noise control technology for rotary drilling. Efforts have been made to improve a mechanical model

of roof bolt drilling with the inclusion of noise generation mechanism. The model can be used to estimate the required drilling thrust and torque, specific energy, energy efficiency, noise level for specified rock strengths. Drill bit design and worn condition can be also considered in the simulation process.

**9:41 AM**

15-066

## **Pushing Automation of Shearer Loaders to the Next Level – Horizon Control Through Usage of Cutting-Induced Dust**

*K. Nienhaus and N. Fietz; Institute for Mining and Metallurgical Engineering, RWTH Aachen University, Aachen, Germany*

Automation of mining processes can increase mine safety as well as productivity. In order to push automation of shearer loaders to the next level, the IMR at RWTH Aachen University has been working on the possibilities of utilizing laser-induced breakdown spectroscopy (LIBS) analysis on released mining dust for horizon control. Since shearer loaders are equipped with water sprays a great amount of released dust is directly bound with water during cutting. Hence, the idea is to analyze this mixture for determining the coal contents of excavated material. Although state-of-the-art devices can determine the amount of airborne dust fractions up to 35 $\mu$ m there is no current method for measuring the concentration of coarser and water-bound particles. The challenge is to design an enclosure enabling LIBS analyses without affecting the operation. Therefore, the IMR worked on the principal design of a dust transport system and an enclosure meeting these requirements. The next step is to determine the amount of generated dust available for analysis. This article will give an overview on the conducted research and emphasizes on the possibilities of automating shearer loaders by dust analysis.

**9:59 AM**

15-052

## **Surface Chemistry Modification of Rock Dust for Improved Dispersion and Coal Dust Explosion Prevention**

*Q. Huang, R. Honaker, K. Perry and L. Braden; Mining Engineering, University of Kentucky, Lexington, KY*

Rock dust is applied in underground coal mines to prevent coal dust explosions. The application is conducted either dry or wet. Both methods have advantages and disadvantages however the formation of caked rock dust particles is sited as a significant concern for wet applications. A study was conducted to evaluate the effect of modifying the rock dust particle surfaces to repel water and each other by the addition of oleic acid (OA) and sodium oleate (NaOL). At a NaOL dosage of 2 lbs/ton, a contact angle of 68 $^{\circ}$  was measured indicating strong surface hydrophobicity and ability to repel water while the surface charge increased to a more negative value thereby enhancing particle dispersion. Fourier Transform Infrared Spectroscopy (FTIR) tests indicated a chemisorption mechanism which is necessary for long term stability of the surface modification. The dispersion rate of the modified rock dust samples was elevated

by the application of both OA and NaOL thereby indicating a significant reduction in the detrimental effect of caking. Tests in an explosion chamber showed a 67% reduction in the dust explosion potential relative to untreated rock test applied by the wet technique.

**10:17 AM**

15-048

### **A Preliminary Study on Thermal Probe Technology Against Coal Storage Pile (Gangue Hill) Spontaneous Combustion**

*D. Jun<sup>2</sup> and B. Li<sup>1</sup>; <sup>1</sup>College of Energy Science and Engineering, Xi'an University of Science and Technology, Xi'an, China and <sup>2</sup>Key Laboratory of Western Mine Exploration and Hazard Prevention, Ministry of Education, Xi'an University of Science and Technology, Xi'an, China*

The spontaneous combustion of coal storage pile(Gangue Hill) is one of the seriously threat encountered in coal mining and storage. In order to prevent spontaneous combustion of coal storage piles (hillock) due to regeneration, a method using heat pipes to destroy the heat preservation conditions of coal storage pile(Gangue Hill) is proposed, which reduces the risk of coal spontaneous combustion and prevents coal fire. An experimental equipment of the heat transferring in a set of heat pipe, which used to study the influence on coal pile temperature distribution, has been designed. Results show, the heat pipe has a significant effect on inhibiting the coal spontaneous combustion process by destroy the heat preservation conditions of the coal. Under the experimental conditions, the most obvious coal temperature decline appears at radius 20.0mm around the pipe, dropped from 45.8°C to 32.5°C, a decline of 29%; the coal pile temperature at radius 420mm from 12.9°C to 12.4°C, a decline of 3.87%. And the research offers an effective and new approach in its application and promotion for preventing and controlling in coal spontaneous combustion.

**10:35 AM**

15-128

### **Determination of the Fire Hazards of Mine Materials Using a Radiant Panel**

*S. Harteis, C. Litton and R. Thomas; Fires and Explosions Branch, NIOSH, Pittsburgh, PA*

The objective of the study was to develop a laboratory-scale method to rank ignition and fire hazard of commonly used underground mine materials and to eliminate the need for expensive large-scale tests that are currently being used. The radiant panel apparatus was used to determine the relevant thermal characteristics of the materials: time to ignition, critical heat flux for ignition, heat of gasification, and mass loss rate. Three thermal parameters, TRP TP1, and TP4, derived from the measured values, were developed. The parameters were used to rank the overall ignition and fire hazards of the combustible materials from low to high hazard. The results compared favorably with thermal and ignition hazards of similar materials reported in the literature and represent a simpler approach to quantify these combustible hazards.

**10:53 AM**

15-039

**MulsimNL/Large: Reviving A USBM Tool for Modeling Coal Mines***M. Larson; Ground Control Branch, NIOSH, Spokane, WA*

Specialized numerical codes have been developed over the years to model the excavation of coal in underground mines. This paper traces development of MulsimNL/Large, summarizes its capabilities and describes the types of problems that have been successfully addressed. Recent work modeling deep western longwall coal mines has demonstrated that MULSIM has distinct advantages for regions with relatively stiff and strong overburden. This work required that Mulsim be revived and updated into a version called MulsimNL/Large. Updates included larger array sizes, greater precision, greater number of materials, and the addition of a 6-segment/five-point constitutive model that provided the user a more flexible coal-strength law having the capability to follow hardening and softening before reaching a final residual strength. In addition, the work of Johnson et al. in developing functions that represent yield strength variation by location in a pillar for various average pillar strength formulas were easily implemented. Moreover, custom variation of pillar stress-strain curves derived from detailed models such as FLAC3D were executed without difficulty.

**11:11 AM**

15-036

**Impermeable rock groups deformation during partial backfill mining of shallow coal mines***W. Zhang, W. Dong and Z. Feng; Hydrogeology, Xi'an Research Institute of China Coal Technology & Engineering Group Corp, Waterloo, ON, Canada*

Western China has many shallow coal seams. Mining of these shallow seam contributes to environmental deterioration in part due to disruption of groundwater sources. The lowering of the phreatic surface is attributed to the instability of the impermeable rock groups as a result of mining. leading to an increase in permeability and drop in phreatic surface. Underground mining with partial backfilling is one of the fundamental methods of controlling the lowering of the water table in sensitive cases. At present, there has been no research on the laws governing the movement of impermeable rock groups in partial backfill mining. this research, conducted in the Yu Shen-fu region of Western China, developed similar material of sand-based paste filling materials, tested the mechanical parameters of similar material of sand-based paste filling materials, researched on long wall partial backfill mining through similar simulation experiments, obtained the development of "upward fractures" and "downward fracture" under different gap-filling widths and body-filling widths and the movement law of impermeable rock groups under different gap-filling widths and body-filling widths.

## **Coal & Energy: Underground Mining Processes and Practices**

**9:00 AM • Tuesday, February 17 • 502**

*Chairs: G. Buchan<sup>1</sup>, Norwest Corp., Pittsburgh, PA  
R. Wagner<sup>2</sup>, PBS Coals, Somerset, PA*

**9:00 AM**

### **Introductions**

**9:05 AM**

### **Roof and Pillar Failure Associated with Weak Floor at a Limestone Mine**

*M. Murphy<sup>1</sup>, G. Esterhuizen<sup>1</sup>, J. Ellenberger<sup>1</sup> and T. Miller<sup>2</sup>;  
<sup>1</sup>Office of Mine Safety and Health Research, National Institute for Occupational Safety and Health, Pittsburgh, PA and <sup>2</sup>East Fairfield Coal Company, Petersburg, OH*

A limestone mine in Ohio has had pillar instability problems that have led to massive roof falls extending to the surface. During the NIOSH investigation into pillar instability, weak floor was identified as a potential hazard, but no case histories existed of weak floor related instability. The Stone Mine Pillar Design software indicates that the stability factors for these pillars are high, mostly due to their high uniaxial compressive strength. However, S-Pillar specifically does not include analysis for weak floor since there are not enough case histories and the issue should be investigated further using a more advanced analysis. Numerical models have been implemented to help determine the exact failure mechanism at the mine. Roof to floor extensometers have also been installed in the areas predicted to have further instability. This case study will provide important information to limestone mine operators regarding the hazards of weak floor and the potential for roof collapse, pillar failure and subsequent subsidence of the ground surface. This recent case demonstrates that weak floor is a real hazard and will alert stone mine operators and designers of this potential hazard.

**9:25 AM**

**15-109**

### **Ground Control Tools in Underground Coal Mining – Conveniences and Precautions**

*S. Bhattacharyya<sup>1</sup> and M. Nelson<sup>2</sup>; <sup>1</sup>Underground Mining, Norwest Corporation, Salt Lake City, UT and <sup>2</sup>Mining Engineering, The University of Utah, Salt Lake City, UT*

Coal bearing rocks are low in strength and have geological discontinuities and moisture sensitivity. Roof and rib falls have been a major cause of fatalities in underground coal mines. Mine engineers design ground control plans for regulatory approvals. A number of tools are available from the National Institute for Occupational Safety and Health to design and assess these plans. Quite often there is not enough geotechnical input information available and databases are used. The Appalachian coalfields have extensive scientific studies to provide reliable

regional inputs. Coal mines in the western United States and Canada have different geological and geotechnical conditions, and less available data. Use of inappropriate inputs in the tools like Analysis of Retreat Mining Pillar Stability, Analysis of Longwall Pillar Stability, and Analysis of Roof Bolt Systems may result in unsafe designs or over conservative designs. The tools are convenient but thorough understanding of the inputs, calibration with local test results, and operating experience are important for effective designs. The current paper contains examples of difficulties faced during mine planning using the above tools.

**9:45 AM**

### **A Case Study of a Low Overburden Longwall Recovery with Pre-Developed Recovery Entries**

*B. Hanson<sup>1</sup>, R. Ochsner<sup>1</sup>, J. Stankus<sup>2</sup> and X. Li<sup>2</sup>; <sup>1</sup>Signal Peak Energy, LLC, Roundup, MT and <sup>2</sup>Jennmar Corp., Pittsburgh, PA*

The 3 Right pre-developed longwall recovery entry at Signal Peak Energy's Bull Mountain No. 1 mine was designed to prevent the abnormal roof conditions encountered in its first two recovery entries. Unique geological conditions, such as the low overburden of approximately 200 feet and prevalence of roof joints in the sandstone overburden, contribute significantly to abnormal conditions during longwall recovery. The 3 Right recovery entry was 42ft wide and developed in two stages, 21ft wide in each stage. The entry roof was reinforced with steel wire mesh/non-metallic recovery mesh, high-capacity primary bolts and cables. After all the support was installed, the entry was completely backfilled with specially designed, cuttable, low-density cement. The support design was completely successful with a smooth cut-through on January 29 and 30, 2014, creating a record in retrieving the shields within 15 days, not to mention the safest working environment for protecting the miners. Based on actual observance and practices of the 3 Right recovery entry, recommendations on improvement and modifications of roof support for 4 Right recovery room are presented.

**10:05 AM****15-016**

### **Strata Mechanics of Pillar Mining at the Crandall Canyon Mine**

*W. Pariseau; Mining Engineering, University of Utah, Salt Lake City, UT*

Recent advances in numerical modeling of tabular deposits, such as coal mines in the Wasatch Plateau field in central Utah, allow for whole-mine analysis based on first principles. Subsidence estimates in three-dimensions at the kilometer scale are possible, while details of stress concentration about main entries, barrier pillars, chain pillars and so on can be obtained at a scale of a few meters. Application to the Crandall Canyon Mine during barrier pillar mining in 2007 demonstrates the technique. Three-dimensional subsidence and seam-level results indicate what previous two-dimensional finite element analyses (Pariseau, 2011) have shown: pillar design should be based on computer programs that lead to detailed distributions of stress, strain, and displacement in pillars and adjacent roof

and floor strata all while allowing for long distance transfer of stress and interaction between all sections in a mine. Inclusion of the effects of joints and variability of properties on strata mechanics are additional steps towards greater realism in numerical modeling of tabular deposits. Examination of mine-induced seismicity reinforces this conclusion.

**10:25 AM**

## **Diesel Emission Control Solutions**

*G. Robb; AirFlow Catalyst Systems, Inc., Rochester, NY*

Catalyzed Diesel Particulate Filters (CDPFs) and Diesel Oxidation Catalysts (DOC) have gained wide acceptance in the treatment of diesel exhaust for underground mining equipment. AirFlow Catalyst Systems continuously develops its products to passively oxidize diesel particulate matter (DPM), CO and HC while maintaining NO<sub>2</sub> levels at or below engine out. AirFlow Catalyst Systems works closely with our customers through a proven solution process to ensure complete satisfaction. This process starts by gathering detailed engine, equipment and usage information along with emissions issues and concerns. AirFlow performs a detailed analysis of temperature data to determine the optimum product and sizing. AirFlow provides a system design that conveniently fits with the specific equipment. Finally, AirFlow is present during startup to ensure desired performance. AirFlow combines its products and solution process with real time operational feedback in the form of a system monitor to provide the best ongoing solution for its customers. The system monitor displays backpressure and temperature data to help the equipment operator predict, and in many cases avoid, filter maintenance.

**10:45 AM**

15-057

## **Risk Management: Adapting RISKGATE for underground coal mines in the United States**

*E. Jong<sup>1</sup>, K. Luxbacher<sup>1</sup>, P. Kirsch<sup>3</sup>, R. Mitra<sup>2</sup>, B. Hebblewhite<sup>2</sup>, S. Schafrik<sup>1</sup> and B. Conley<sup>1</sup>; <sup>1</sup>Mining and Minerals Engineering, Virginia Tech, Blacksburg, VA; <sup>2</sup>School of Mining Engineering, University of New South Wales, Sydney, NSW, Australia and <sup>3</sup>Minerals Industry Safety and Health Centre, The University of Queensland, St. Lucia, QLD, Australia*

The underground coal mining industry in the U.S. has recently experienced several high profile, multi-fatality events. The explosions that occurred at the Sago Mine in 2006, the Darby Mine in 2006, and the Upper Big Branch Mine in 2010 have caused a ripple in an otherwise steadily improving safety record. These events transpired in the midst of an unprecedented level of government regulations and modern safety technologies. This recent increase in fatal events in conjunction with a minimal decline of fatal and non-fatal injuries over the past decade may signify that current safety practices have reached a level of diminishing returns. Risk management, a safety approach that has been successfully applied in various heavy industries, may provide a means to surpass the safety plateau in the U.S. RISKGATE is an Australian mining risk management program that shows great potential for application in the U.S. However, fundamental differences between coal mining in Australia and in the U.S. prevent direct implementation. This paper discusses

aspects of the RISKGATE body of knowledge that require some adaptation before this program may be applied to the U.S. mining industry.

## **Coal & Energy: Ventilation: Best Practices II**

**9:00 AM • Tuesday, February 17 • 505**

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

**9:00 AM**

### **Introductions**

**9:05 AM**

15-035

### **Realtime Diesel Particulate Matter Monitoring In U.S. Underground Mines**

*M. Khan and S. Gillies; Mining and Nuclear Engineering, Missouri S & T, Rolla, MO*

Underground mine diesel equipment generally offers more flexibility as compared to electric powered systems. Diesel exhaust is an adverse agent which affects the health of underground miners. The National Institute of Occupational Safety and Health (NIOSH) regards diesel exhaust as carcinogenic. The NIOSH 5040 method is an established technique for measuring Diesel Particulate Matter (DPM). This process inherently involve a lag time before an accurate exposure determination can be made during which miners are potentially overexposed to DPM. This issue can be addressed by using realtime DPM monitors. This paper presents underground mine shift average based and realtime monitored DPM from US mines. A FLIR Airtec instrument has been used for realtime measurement whereas shift average based DPM has been determined by the use of NIOSH 5040 method. A log of diesel equipment movement was maintained. DPM concentrations versus time were plotted and analyzed. High DPM sources were identified and the FLIR Airtec was demonstrated to be satisfactory for realtime DPM measurements.

**9:25 AM**

15-145

### **Case study - PVC Vent duct road map from Product development to ventilating underground mining operation**

*A. Rai; Barrick Turquoise Ridge Inc, Winnemucca, NV*

Historically, Auxiliary ventilation has always been a challenge with limited air quantity in dead-end entry or working face. The PVC low frictional factor, low physical constraint and minimum leakage ventilation duct was development with "made in US and used in US". The PVC duct development covering operational and total cost of ownership with on-going success will be pre-

sented. This paper will discuss different mine sites using new PVC vent duct underground and the results from operational and technical side making a difference.

**9:45 AM**

### **Determination of Contraction Factor for Flow Regulators**

*M. Shriwas<sup>1</sup>, G. Pawar<sup>2</sup> and F. Calizaya<sup>3</sup>; <sup>1</sup>Mining Engineering, University of Utah, Salt Lake City, UT; <sup>2</sup>*

A regulator is an obstruction in an airway used to restrict the flow directed to a working area. Its size is usually defined as a function of a parameter referred to as regulator resistance. This on the other hand depends on the differential pressure across the opening, air velocity, and a constant referred to as contraction factor. In practice, this factor is not a constant. It varies with the geometry and location of the opening in the airway. A laboratory scale auxiliary ventilation system was set up to investigate the problem. The system includes a blower fan in a circular duct and a regulator of adjustable cross-section. Several experiments were conducted by varying the regulator cross-sectional area and by measuring pressure drops and flow rates for different fan duties. Preliminary results showed that the contraction factor varies from 0.75 for concentric regulators to 0.83 for non concentric regulators. This study presents the results of these experiments and the calculated contraction factors for different types of regulators.

**10:05 AM**

15-046

### **Study on the Spontaneous Combustion Characteristic of Jurassic Coal in West China Based on the Programmed heating experiment**

*J. Deng, K. Wang, X. Zhai, H. Wen and Y. Zhang; Xi'an University of Science and Technology, Xi'an, China*

The Jurassic coal fields in west China is the major energy base and contain half of coal resources in China. Due to the gather and degeneration rules, the spontaneous combustion characteristic of Jurassic coal are distinguished with permo-carboniferous coal. Programmed heating experiments of five Jurassic coal samples and three permo-carboniferous coal samples from different primal coal fields in West China were conducted to identify the characteristic parameters in the low temperature stage of oxidation. The experiments were carried out under non-isothermal heating conditions up to 453.15K at the heating rate of 0.33K/min in an air atmosphere. The result showed that oxygen consumption rate, CO gas production rate and heating intensity of all coal samples increased with the rising of the temperature, and Jurassic coal of which was higher than that of permo-carboniferous coal. The generation of C<sub>2</sub>H<sub>6</sub> and C<sub>2</sub>H<sub>4</sub> organic gas of Jurassic coal was earlier and more in the process of oxidation and spontaneous combustion. It indicated that Jurassic coal was easier to be oxidated, and the index of spontaneous combustion was different between Jurassic coal and permo-carboniferous coal.

**10:25 AM**

15-024

**Air Leakage and Air Recirculation Behavior under the Influence of Booster Fans***K. Feledi; Mining and Nuclear Engineering, Missouri University of Science and Technology, Rolla, MO*

Ventilation is critical to underground mining. As mining progresses the total air resistance of an excavation is increased, the mine characteristic curve becomes steeper, and the operating point moves up the fan curve, reducing the total air quantity and increasing the system pressure. For multi-level ventilation networks with both main and booster fans the process can be complex, and the optimal combination of fans can be very hard to achieve. This paper details experiments and results carried out at Missouri S&T Experimental Mine that investigated air leakage and recirculation caused by the use of booster fans. The results were compared with the situations where booster fans are used and not used. The variables considered were the booster fan blade angle and the fan combinations. Air quantity measurements were taken at each individual stopping under a number of scenarios and across four blade angle settings. The first set of situations examined were 1) the main surface Joy fan only running, 2) main fan and the west booster fan running, and 3) the main fan and east booster fan running. Higher fan blade angles introduced more recirculation than lower blade angles.

**Environmental: Responsible Mining  
Environmental and Social Risks I****9:00 AM • Tuesday, February 17 • 105***Chairs: M. Jarvie Eggart, Barr, Marquette, MI  
C. Kearney, Barr Engineering, Hibbing, MN**Sponsored by: MWH Global***9:00 AM****Introductions****9:16 AM****Environmental Cost vs Benefit***J. Renner; Southern Ionics Inc., Saint Simons Island, GA*

Environmental stewardship takes effort not directly associated with mineral production, so environmental resources are usually accounted as costs to a business. "Cost" has a negative connotation, and the standard business approach to managing "costs" is to reduce them. This perception of environmental resources is narrow-minded. Resources have value, and the values can be negative (costs) or positive (benefits) depending on how the resources are managed. Unfortunately, one way to reduce costs is to reduce the effort applied to them. Thus, environmental stewardship may be perceived as another cost, instead of as an investment with the potential for a large positive return if environmental resources can be managed so that costs are transformed to benefits. Flipping the value requires broad

perspective. Engage stakeholders to build strong relationships. Understand local and regional conservation and community goals, and strive to achieve goals that may be independent of or extend beyond the company's specific business aims. Invite involvement of parties that may not typically be allies. Turn regulatory adversaries into conservation partners.

**9:32 AM**

## **Successful Non-Ferrous Mining; Promise or Reality?**

*P. Eger; Global Minerals Engineering, Hibbing, MN*

Horror stories from historic metal mines are easy to find – but are there any examples of successful mining operations? Can we really have jobs and environmental protection? Newer mining operations have successfully operated and closed and current operations have developed relationships with the community that minimizes confrontation. Examples of successful mines including the Flambeau Mine in Wisconsin, the Ridgeway Mine in South Carolina and Stillwater Mines in Montana were selected from a larger initial list and their operations reviewed in detail. Factors that contributed to the success of these operations included: a commitment to environmental protection, good working relationships with regulatory agencies, an open and active community outreach program, persistence and a willingness to go above and beyond to solve problems, an adaptive management approach, and long term post closure monitoring.

**9:48 AM**

15-127

## **Preventing Coal Waste Impoundment Breakthroughs into Underground Mines. How Well Are We Doing?**

*P. Michael<sup>1</sup>, M. Richmond<sup>2</sup>, S. Self<sup>1</sup>, J. Shapaka<sup>1</sup> and J. Mack<sup>1</sup>;  
<sup>1</sup>Appalachian Region Office, U.S. Office of Surface Mining Reclamation and Enforcement, Pittsburgh, PA and <sup>2</sup>Charleston, WV Field Office, U.S. Office of Surface Mining Reclamation and Enforcement, Charleston, WV*

In response to the October 11, 2000 impoundment breakthrough into an underground mine in Martin County, eastern Kentucky, the U.S. Office of Surface Mining Reclamation and Enforcement (OSMRE) commissioned an oversight study that evaluates how well state and federal regulatory programs established under the Surface Mining Control and Enforcement Act are ensuring that impoundment operators are minimizing the potential for impoundment-basin breakthroughs. The study focuses on slurry impoundments constructed in the hollows of Appalachia where numerous coal seams and steep topography combine to result in a large number of mined seams intersecting and underlying impounding facilities. Factors under consideration include: full accounting of all mineable coal seams intersecting and underlying the impoundment; identification and accurate location of underground mines close enough to the impoundment to potentially affect its stability; assessment of the stability of coal barriers between the impoundment basin and adjacent mines, and stability of roof rock and pillars in mines subjacent to the structure; assessment of slurry flowability; and measures taken to reduce breakthrough potential.

**10:04 AM****Creative Mine Water Management Solutions***C. Kearney and K. Matson; Barr Engineering, Hibbing, MN*

Responsible water management is critical to positive social, environmental, and economic outcomes for any mining operation. Regulators, water resource managers, and local populations are increasingly apprehensive about mining's potential impacts on water availability and water quality, and the mining industry is responding to these concerns. Many mining operations have instituted responsible mine water management measures, including water recycling and use of low-quality water, to continue to operate and even expand while facing global competition for water. This presentation discusses innovative techniques that mining companies are using to reduce impacts to water resources.

**10:20 AM****Groundwater Modeling: Opportunities and Pitfalls in Effective Mine Water Management***D. Edington; Schlumberger Water Services, Denver, CO*

Effective application of models requires one to have an informed perspective on the opportunities that models provide yet one must also have an awareness of their pitfalls. "All models are wrong but some are useful" expresses this duality that all models have. All models are human constructs that help us better understand the natural world. All models are wrong due to a long list of reasons including simplifying assumptions, misunderstood processes, inadequate and incomplete knowledge of the site, errors in measurement and interpretation of field data, heterogeneity and scale issues, calibration non-uniqueness, and errors related to numerical implementation. Nevertheless, "some models are useful" if one understands what models are, what they are designed to do, what their strengths and limitations are, and the common pitfalls to watch for. A model's usefulness must be evaluated in the context of "fit for purpose." Models are useful because they provide a means to test assumptions, evaluate options, quantify confidence intervals, and to improve decision making. Models can reveal aspects of the hydrologic system that encourages deeper investigation and understanding.

**10:36 AM****Advanced Automated Radar-based Bird Control Technologies for Reducing Impacts at Waste Ponds***K. Voltura, J. Quillen, C. Matkovich, J. Lewis and J. Davenport; DeTect, Inc, Panama City, FL*

Bird mortality at large waste ponds at mines, oil sands, and other large-scale industrial facilities has presented environmental and public relations challenges to the industry. Advanced bird radar originally developed for and in use by military aviation for bird-aircraft strike prevention has been combined with hazing device technologies and applied to oil sands, potash and oil/gas waste impoundments for bird control. MERLIN Bird Control Radar Systems are an on-demand bird detection and deterrent system that uses a combination of horizontal surveillance

radars, Acoustic Hailing Devices and lasers to automatically and simultaneously detect and deter bird activity at waste ponds. Efficacy studies were used to document deterrence rates at an oil sands facility. Reporting features using Microsoft SQL provide options for automated report generation, allowing quicker awareness of and response to patterns and changes in both bird and hazing activity as well as more efficient management of environmental reporting requirements. Analysis of the high quality radar data can also support adaptive management strategies by revealing how wildlife use the site and areas at risk for impacts.

**10:52 AM**

15-019

### **The Study of Optimum Tailing Storing Conditions for Surface Paste Disposal Method**

*A. Bascetin, S. Tuylu, D. adiguzel and U. Akkaya; Mining Engineering, Istanbul University, Istanbul, Turkey*

One of the main problems for storing of the tailings is acidity occurrence due to several factors such as existence of sulfuric minerals and also the pollution in seepage waters by mobilization of metal ions, which holds great risks in terms of environmental regulations. Because of these specified reasons, tailing materials to be used in a SPD formula should have comply with some specifications. Among these properties; oxygen content, temperature, matrix suction and pH are the most important parameters. In the study, the relationships between the parameters mentioned are investigated to reveal optimum paste design layout. The reactions occurring according to the oxidation, as seen at seepage water of second and third layers, decreased the pH of system to the under of 7 value. Additionally, when the seepage water of first layer's EC value is 2.93 mS/cm, the EC value of second layer is increased at 3.54 mS/cm. The other parameters are evaluated with the obtained results of the tests to determine the optimum storing conditions for SPD.

**11:08 AM**

15-142

### **The Elk River, West Virginia MCHM Spill: A Case Study on Risk Management for Nonhazardous Chemicals**

*M. Scaggs, E. Sarver and L. Rojas Mendoza; Mining and Minerals Engineering, Virginia Polytechnic Institute and State University, Blacksburg, VA*

On January 9, 2014, a large chemical spill occurred on the bank of the Elk River near Charleston, WV. Within hours, the potable water supply for more than 300,000 people was contaminated, and the incident captured national headlines for weeks. Although the chemical, crude MCHM, is deemed nonhazardous, the impacts of the spill are significant – with all stakeholders, including the public, industry and government experiencing losses. This case highlights the need for a more proactive approach to environmental management, shifting from crisis control and remediation to crisis prevention and risk management.

**Environmental: Sustainable Reclamation/  
Remediation****9:00 AM • Tuesday, February 17 • 107**

Chairs: **B. Nielsen**<sup>1</sup>, Freeport-McMoRan Copper and Gold, Phoenix, AZ

**A. Cooper**<sup>2</sup>, Freeport-McMoRan, Inc., Oro Valley, AZ

**9:00 AM****Introductions****9:05 AM****Natural Channel Design, a Reliable and Flexible Solution to Remediating Mine Impacted Streams**

*M. Mangold; Engineering and Environmental Management, TREC, Inc, Bozeman, MT*

Natural channel design has slowly become a proven alternative to “rigid” channel armoring on stream remediation projects. With an ever increasing value placed on streams and riparian ecosystems, permitting agencies favor the natural channel concept and recognize the dynamic nature of stream systems. As a result, permitting of a “soft” natural channel design is often streamlined and strict performance standards are avoided which reduces maintenance obligations and liability. Key advantages of natural channel design include utilization of onsite resources and field fitting yielding more sustainable and naturally aesthetic landscapes and positive public perception. Multiple stream reclamation projects on a legacy mining site will be presented that involve mine waste removal from the stream corridor to improve surface water quality and overall ecosystem through development of self-sustaining vegetation and bank treatments to facilitate long-term system stability. Discussion includes design strategy and details, permitting challenges, construction implementation and lessons learned.

**9:25 AM****Sustainable Phytoremediation to Remove Leachate**

*H. Halderman; TRC Solutions, Bozeman, CO*

A landfill located in Baton Rouge, Louisiana contained spent slurried bauxite residues (red mud) from a plant that used bauxite, reacted under pressure with hot caustics, to produce alumina. Leachate (with high aluminum, arsenic, barium, and vanadium concentrations) was identified seeping from impoundment sidewalls and potentially flowing to adjacent water bodies. The State of Louisiana ordered installation of a collection system to prevent further seepage. TRC designed and installed a patented phytoremediation technology, TreeWell®, which resulted in a sustainable solution for leachate removal to depths greater than 15 feet below surface. The TreeWell® System utilizes the landfill leachate as a water source, eliminating off-site migration. Sustainable benefits include offsetting environmental impacts

(CO<sub>2</sub> emissions) compared to traditional mechanical systems, removing additional CO<sub>2</sub> through plant uptake/carbon sequestration, significantly reducing long-term costs (no leachate transportation/disposal or electrical costs to operate pumps, etc., and minimal maintenance required), while providing an esthetically pleasing space.

**9:45 AM**

### **Using a Multi-Criteria Analysis Tool to Incorporate Sustainability into Remedial Alternatives Analysis for Minesites**

*D. Crawford and F. Shuri; Golder Associates, Redmond, WA*

This paper provides a multi-level approach to alternatives analysis for closure operations that incorporates sustainable principles in the remedial alternatives analyses. Using a conceptual site model for each alternative, semi-quantitative scores were developed for each of the factors that may be considered in the development of remedial alternatives. These factors include traditional exposure pathways and receptors, physical hazards that may be encountered, plus sustainable principles that may be applied to the remedies. An example of a remedial alternatives analysis for closure of a property affected by mining operations is reviewed in detail.

**10:05 AM**

15-079

### **Application of Sustainability to CERCLA Remedy Selection**

*B. Nielsen<sup>1</sup> and L. Holder<sup>2</sup>; <sup>1</sup>Freeport-McMoRan Inc., Phoenix, AZ and <sup>2</sup>Golder Associates, Redmond, WA*

The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), commonly known as Superfund, mandates evaluation of remediation alternative using nine criteria: (1) overall protection of human health and the environment, (2) compliance with ARARs (applicable or relevant and appropriate standards), (3) long-term effectiveness and permanence, (4) reduction of toxicity, mobility or volume, (5) short-term effectiveness, (6) implementability, (7) cost, (8) state acceptance, and (9) community acceptance. Many states have adopted these or similar criteria for remedy selection under state laws. Sustainability is not explicitly addressed in these criteria, but consideration of sustainability can be incorporated into these criteria. This paper explores how sustainability can be evaluated for remedy selection using the CERCLA criteria.

**10:25 AM**

### **Lower-Impact Heap Leach Pad Cap Design using Natural “Armoring” Process Modeling**

*G. Annandale and A. Joslyn; Golder Associates, Mt Laurel, NJ*

This presentation will discuss a successful design of a closure cap for a heap leach pad using natural processes to reduce resource consumption. The approach is based on research by Gessler (1970) to estimate the final grain size distribution

of a soil after winnowing of fines by the shear forces of flowing water. This process is known as “armoring” and Gessler found that the final particle size distribution of the soil can be estimated based on modeled surface water shear stress. A case study will be presented demonstrating how a uniform cap was designed using this approach to replace a failed cap on a heap leach pad. The original cap was designed without appropriate consideration of natural processes. The uniform cover designed using the Gessler model allowed for use of an inexpensive local source material that was less environmentally damaging than obtaining off-site materials from resource-intensive sand and gravel operations.

**10:45 AM**

### **Remote Controlled Monitoring**

*G. Heath<sup>1</sup>, K. Stoll<sup>1</sup>, M. Poulton<sup>1</sup>, M. Momayez<sup>1</sup>, J. Haynes<sup>2</sup> and M. Smith<sup>2</sup>; <sup>1</sup>Mining and Geological Engineering, University of Arizona, Tucson, AZ and <sup>2</sup>Carlota Copper Company, KGHM International LTD., Miami, AZ*

With an increase in mine closure activities including greater emphasis on reclamation, the industry is faced with a greater need for thorough, inexpensive, and better regulated environmental remediation procedures. Indefinite sampling and monitoring of these sites are necessary even after reclamation has been deemed successful. The approach to monitoring for a mine closure project is predicated on developing a low cost, integrated, autonomous system that includes networked geophysical, hydrological, and self-calibrating general chemical sensors backed by a secure, integrated web-based data storage and retrieval software system. The solar powered system enables 24/7 remote access to the sensors, data storage units, and control system.

**11:05 AM**

### **Valuable Acid Recovery from Waste Streams**

*P. James and M. Baker; Blue Planet Strategies, Madison, WI*

Sulfuric acid is widely used to promote metal leaching in mining and often represents a costly consumable which is spent by the leaching process. This represents a considerable resource. Here on-site sulfuric acid regeneration as a byproduct of BPS's versatile DEMET technology is shown and represents a new and recently demonstrated application for BPS's versatile DEMET dilute source metal recovery and concentrating technology. A discussion of the process and examples of relevant chemistry is provided. Results from treatment of a representative target mine waste stream will also be examined. Observed process effectiveness and removal efficiency will be illustrated along with exploration of potential options for transformation of the raw byproduct acid into higher concentration and more pure product suitable for sale and NEW revenue generation. Process economics for a representative case will be examined along with considerations for estimating the range of feasible application scenarios.

**Environmental: Water Treatment I:  
The Problem of Dissolved Salts****9:00 AM • Tuesday, February 17 • 106**

Chair: **S Benowitz**<sup>1</sup>, *Water Engineering Technologies Inc., Bozeman, MT*

**M. Mierzejewski**<sup>2</sup>, *CH2MHill, Richmond, VA*

Sponsored by: **Veolia Water Solutions**

**9:00 AM****Introductions****9:05 AM**

15-089

**A Case History on Reduction of Chlorides  
from Mine Water**

*S. Muddasani; Veolia water, Pittsburgh, PA*

Mine water contains both dissolved and particulate solids. Dissolved solids primarily consist of chlorides and sulfates. When discharged to a receiving stream without treatment, these constituents create a potentially toxic environment for aquatic life. A case study is presented to discuss how a centralized treatment plant treat mine water from six locations to meet discharge limitations for chlorides. Located in West Virginia, this facility achieves less than 218 mg/l chlorides in the discharge while generating zero liquid waste. The dissolved solids concentration in the influent ranges between 8,000 and 10,000 mg/l, with chloride concentrations of 1,000 to 2,000 mg/l and sulfate concentrations of 5,000 to 6,000 mg/l. The mine water is treated using advanced treatment technology to produce clean water for discharge or reuse. The treatment process is comprised of aeration, softening, filtration, reverse osmosis, RO reject softening, evaporation, crystallization, final effluent remineralization and sludge dewatering. The solid waste generated in the treatment process is land filled on site. Because no liquid waste leaves the system, this plant is a Zero Liquid Waste (ZLW) facility.

**9:25 AM****Forward Osmosis: The Solution for Brine  
Concentration**

*L. Herrmann and R. Zuback; Oasys Water, Boston, MA*

Mining wastewaters commonly contain high levels of dissolved solids and high hardness. Concerns such as scaling, energy usage, space limitations, and disposal costs make mining wastewater treatment a unique challenge that traditional treatment methods cannot efficiently or cost effectively handle. Forward Osmosis (FO) is an innovative technology that can alleviate these concerns for the mining industry. The FO process pulls fresh water from the feed across a thin membrane into a more concentrated draw solution. The diluted draw solution and water are then separated, providing fresh water for benefi-

cial reuse or safe disposal. The FO process does not require a pressurized vessel, which reduces potential for scale formation. Unlike evaporators, the feed water is never boiled, thus reducing the amount of energy required for separation. The modular membrane system design allows for smaller footprints, as is often required at mining sites. FO can concentrate the dissolved solids in the wastewater to nearly 300,000 mg/L, minimizing brine for disposal. Due to these benefits inherent to the process, forward osmosis shows great promise as a solution to the mining industry's water challenges.

**9:45 AM**

15-096

## **New Method for Sulfate Removal and Recovery**

*P. James and M. Baker; Blue Planet Strategies, Madison, WI*

High sulfate levels are commonly encountered in mining influenced waters like PLS (pregnant leach solution), raffinate, heap leach drain down streams, and ARD (acid rock drainage). Recent tightening of sulfate discharge regulations has created additional drivers for treatment and removal of sulfate from wastewaters prior to discharge. Here removal of sulfate from the target stream as a byproduct of being treated by BPS's versatile DEMET technology is considered and represents a new and recently demonstrated application for BPS's versatile DEMET dilute source metal recovery and concentrating technology. An overview of why and how the process works will be presented. Results from treatment of a representative target mine waste stream will be presented. The observed process effectiveness and removal efficiency will be illustrated. Implications and treatment options for utilizing this new process will be explored and contrasted to conventional treatment.

**10:05 AM**

## **Managing Salt - Australian Experiences**

*A. Hodgkinson and J. Lozier; CH2MHILL, Melbourne, VIC, Australia*

Many mines have ceased, or must soon cease, water discharges. This entails careful management of salinity. The final stage of salinity management systems, usually costs the most, and controls the upstream technical choices. To date, membranes, particularly reverse osmosis systems, have mostly been used to provide pre-concentration with more costly evaporative techniques deployed at higher salinities, above around 30 - 50 grams/litre. However escalating costs for energy and equipment has driven many CH2MHILL clients to seek ways to deploy common advantages of membrane methods for the brine concentration task. This paper will report on progress towards a brine concentration approach using a novel combination of traditional water treatment methods now undergoing pilot trials with a CH2MHILL client in Australia. This system, to enable the maximum feasible salinity concentration to be produced from reverse osmosis systems (around 16% TDS), is called the MAX-RO process. This paper will also report on strategies and techniques for ultimate disposal of salt, with a particular focus on current and emerging Australian practices.

**10:25 AM**

15-132

## **The ZLD Treatment of Mine Impacted Water to a Potable Water Quality Level**

*J. Lombardi; Jalema Technologies LLC, Boulder, CO*

“Miwatek” is a So. African mine-water treatment start-up company. Miwatek has developed and pilot demonstrated two proprietary, Zero-Liquid-Discharge (ZLD), AMD treatments that discharge potable quality water. The “Miwatek Brine Treatment” (MBT) and “Miwatek Ettringite Treatment” (MET) methods will be presented and described. Both methods use a membrane treatment to produce clean water and a membrane concentrate. The membrane concentrate is then chemically altered to enable either further membrane processing (MBT) or direct discharge after blending with the membrane pre-treatment permeate (MET). The implied cost of either of the systems is significantly less than other demonstrated ZLD systems.

**10:45 AM**

## **Treatment of Metals and Dissolved Salts by Enhanced Chemical Precipitation and Nanofiltration**

*B. Ball<sup>1</sup>, P. Prakash<sup>3</sup>, D. Eggert<sup>2</sup>, J. Easton<sup>4</sup> and J. Stanley<sup>4</sup>;*

*<sup>1</sup>Parametrix, Inc, Bremerton, WA; <sup>2</sup>Chevron Energy Technology Company, Houston, TX; <sup>3</sup>Chevron Energy Technology Company, Bakersfield, CA and <sup>4</sup>WesTech Engineering, Inc, Salt Lake City, UT*

A treatment process combining enhanced chemical precipitation with nanofiltration was successfully tested in a 20 gpm pilot-scale water treatment plant. The pilot plant equipment was installed at a hard rock mine and was operated for 4 months treating representative inflows. Waters were pre-treated by iron co-precipitation at pH 5.5 with an iron to molybdenum (Fe:Mo) ratio of 7:1 to remove molybdenum. Super-saturation of gypsum and calcium fluoride were achieved in the nanofilter concentrate stream. Key parameters for effective and economical desaturation and removal of sulfate, TDS, and fluoride were determined. With concentrate recycle, overall membrane recoveries for treatment of mine waters ranged between 85 and 90 percent and influent sulfate of 1,300 mg/L was lowered to 300 mg/L, compared to a treatment goal of 600 mg/L. The pilot study demonstrated an effective and economical treatment process for reducing sulfate and fluoride levels and achieving NPDES limits for all regulated constituents. A novel process for removing fluoride to below 1 mg/L using polymeric hybrid anion exchange media was also tested.

**Industrial Minerals and Aggregates: Advances in Industrial Minerals Benefication****9:00 AM • Tuesday, February 17 • 102**

Chairs: **E. Blanco**<sup>1</sup>, Newmont Mining Corporation  
**M. Fan**<sup>2</sup>, Eriez Manufacturing Co., Erie, PA

**9:00 AM****Introductions****9:05 AM****Thermodynamic Approach on Water Temperature Effect to Remove Impurities on Phosphate Flotation Product**

*B. Arista; Engineering, Jose C. Mariategui, Ilo, Peru*

Phosphate Ore beneficiation include attrition, direct/reverse flotation and amine, fatty acid and oleic acid reagent scheme to produce a phosphate final product. Typically a P<sub>2</sub>O<sub>5</sub> recovery of 73-75% and a grade of 29-30% are obtained through metallurgical beneficiation. Nature of the phosphate deposit and sea water process used in this particular test involves additional chlorine contaminant in the final P<sub>2</sub>O<sub>5</sub> concentrate product. Typically sea water report 20,000 g/L of chlorine. Final phosphate concentrate contains 200 ppm of chlorine. Hot water was used to solubilize the chlorine content in the final product. Temperature effect under kinetic approach form is evaluated to establish the adequate regime conditions for chlorine removal from the P<sub>2</sub>O<sub>5</sub> concentrate.

**9:23 AM**

15-011

**Plant Evaluation of a Novel Collector for Improved Silica Flotation**

*L. Moore, A. Fallaw, G. Wang, S. Dobson, C. Parkinson and D. Taylor; Mining, ArrMaz, Mulberry, FL*

Over the years, the decline of high grade ores have become an increasing problem in the global mining industry. As such, techniques and chemistries must change in order to continue to meet the market demand and quality. Reverse cationic flotation of quartz and silicates is one of the most important techniques for generating the industry standard product from minerals such as iron and phosphate ores. Amine collectors are the global standard in such processes. However, as the ore quality continues to decline so must the chemistry change to meet the change in ore composition. This paper will focus on the introduction and full scale application of a novel amine collector towards silica flotation in phosphate beneficiation. This collector yield results that suggests it is capable of improving the phosphate recovery, in this cleaner circuit, to approximately 95% with little to no sensitivity to the everyday changes in feed grade.

**9:41 AM****Colloid Fine Phosphate Particles – Flotation Challenges***E. Blanco; Technical center, FLSmidth, Herriman, UT*

Standard marine phosphate deposit beneficiation include to remove coarse particles, de-sliming, attrition, scrubbing direct/reverse flotation and amine, fatty acid and oleic acid reagent scheme to produce a phosphate as final product. The phosphatic slimes are predominantly colloids of a complex mixture of many minerals like apatite, kaolinite, illnite, montmorillonite, wavellite, quartz, dolomite, and fluorite. Phosphate separation from other minerals is complicated by the heterogeneous coagulation formed. An attempt to disperse these particles for their further separation using electrolyte dispersant was performed. Mechanism of dispersion was in base to surface chemistry, colloid stability, and coagulation mechanism was evaluated through in the process. The process includes pre-selective coagulation of colloids clay and fine-phosphate separation. Results indicate additional P<sub>2</sub>O<sub>5</sub> recovery of 6-10% on the overall phosphate processes. Keywords: Collector, flotation, attrition, scrubbing

**9:59 AM****Sandstone Industrial Process Beneficiation***S. Merrill and E. Blanco; Technical Center, FLSmidth, Midvale, UT*

Selected samples of silica from several projects were evaluated by FLSmidth-Dawson Labs as potential sources oil sands. The samples, which included both sandstone and quartz/quartzite analyzed between 91-92% SiO<sub>2</sub>, 0.2-0.4% Fe, 0.2-0.4% Mg and 0.7-0.9% Al<sub>2</sub>O<sub>3</sub>. Impurities included a variety of iron oxide and alumina-silicate minerals. Beneficiation on this material included attrition (P80 passing of ~400 μm), scrubbing and washing to remove fines. Further removal of impurities was achieved by reverse carbonaceous and iron oxide flotation employing both anionic and cationic collectors. Different reagent scheme processes to remove impurities resulted in a substantial improvement in the quality of most silica sample; the quartz concentrates analyzing 94-97% SiO<sub>2</sub> in the final product. Keywords: Collector, flotation, attrition, scrubbing.

**10:17 AM****Cassiterite Flotation of Fines and Tailings from Gravity Separation***G. Bernal; Oxflo, Cape Town, South Africa*

In this study, the flotation of a sample containing slimes and gravity separation tailings from a South African tin processing plant was examined. The sample contained 0.1% Sn and 2.38 % Fe. Due to the ore's natural pH of 8.2, a mixed chain length Hydroxamate was selected as the flotation collector. Rougher flotation tests showed a concentrate of 1.05% Sn and 6.34% Fe with a recovery of 88% and 19% respectively could be achieved. Further cleaner testwork produced a 7% Sn concentrate in 2 cleaner stages and that this concentrate could be achieved with only a 2-3% loss in Sn recovery per cleaner stage whilst the % Fe content in the concentrates remained relatively unchanged.

**10:35 AM****Using High Pressure Grinding Rolls on Phosphate Ores: Lower Cost, Higher Efficiency and Selectivity***F. Sotillo; PerUsa EnviroMet, Inc., Lakeland, FL*

The use of laboratory high-pressure grinding rolls (HPGR) has been investigated to improve the separation efficiency of dolomite and clay minerals (kaolinite) from apatite. This paper includes characterization studies on dolomitic phosphate ores, data of the applied PerUsa EnviroMet, Inc. physical model of the HPGR to develop preliminary comminution data; and laboratory HPGR evaluations to determine crushing parameters, such as feed rates, rolls speed and gap, and applied torque, pressure and energy. Complementary work on lab rod mill grinding, and flotation studies were conducted to assess dolomite/apatite separation efficiency. The HPGR tests show that commercial products for all mines can be obtained. Recoveries of 74% to 82% of P<sub>2</sub>O<sub>5</sub> and rejections of 46% - 83% of MgO were reported with specific energy consumption of 20% to 50% of that of a laboratory rod mill. In the case of kaolinite/apatite separation prepared at 2x0.02-mm particle size, the results showed an increase in both the recovery from 63.4% to 73.2% of P<sub>2</sub>O<sub>5</sub> and rejection of 70% to 84% of Al<sub>2</sub>O<sub>3</sub>, with specific energy consumption of 3.88 KWh/t.

**10:53 AM****Development of a Mixed Copper Oxide – Sulfide Process***G. Bernal; Oxflo, Cape Town, South Africa*

The development of improved oxide flotation reagents and oxide flotation processes has led to a positive shift in the viability of the mixed copper oxide/sulfide flotation route. This shift promotes the re-evaluation of flotation as a process route for several minerals often considered “non-floatable” in the face of high acid consuming ores. This study compares the performance of a mixed copper oxide/sulfide flotation only process to a separate copper oxide hydrometallurgical and sulfide flotation process. An ore sample from a Peruvian deposit was tested and a mixed oxide/sulfide flotation process was developed using various copper oxide reagent groups.

**11:11 AM****Construction and Startup of a New Heavy Mineral Sand Mine***J. Renner; Southern Ionics Inc., Saint Simons Island, GA*

Southern Ionics Inc. is a southeast regional chemical manufacturer that has entered the heavy mineral sand business. Two mines have been permitted. Construction of the Mission South Mine began in 2013 and mining began in July 2014. Construction of the Mission North Mine is planned for 2015. A Mineral Sand Plant is currently under construction nearby. When the plant begins operating in early 2015, heavy mineral concentrate trucked from the mines will be separated into rutile, ilmenite, leucoxene, and zircon sand products for sale to industry. The mines and plant include many innovations in planning, permitting, technol-

ogy, and operational procedures, including avoiding impacts to wetlands and endangered species, continuous water recycling, no offsite process water discharge, small mine cells, state-of-the-art heavy equipment, dry mining combined with a floating mill, new generation spirals, completely automated wet mill controls, innovative water quality treatment and humate management, and continuous reclamation.

## International I

**9:00 AM • Tuesday, February 17 • 108**

*Chairs: D. Malhotra<sup>1</sup>, Resource Dev Inc  
M. Gavrilovic<sup>2</sup>, GR Engineering Services, Denver, CO*

**9:00 AM**

### Introductions

**9:05 AM**

15-060

### Metallurgical Extraction of Tungsten From a Colombian Mineral

*O. Restrepo Baena and L. Rojas-Mendoza; Materials and Minerals, Universidad Nacional de Colombia, Medellin, Colombia*

Tungsten extraction is a subject of global interest due to its properties. These properties, such as its high melting point, have contributed to the development of metallurgical extraction processes that can be adapted to the particular chemical composition and mineralogy of the ore. In Colombia there is a research deficit in tungsten related areas, and especially with regard to its extractive metallurgy. In this study the physical, chemical and mineralogical characterization of the sample were performed. Subsequently, crushing and grinding were employed to reduce the material to a more convenient size, making it suitable for further concentration and metallurgical processes. Through physical techniques it was obtained a concentrate ranging between 60 -70 % of WO<sub>3</sub> content. This concentrate underwent a leaching stage with a mixture of NaOH and Na<sub>2</sub>CO<sub>3</sub> in order to obtain sodium tungstate. Afterwards the solution was purified by filtration and precipitation steps. The sodium tungstate was converted to ammonium tungstate from which ammonium paratungstate (APT) was obtained by evaporation and crystallization. Finally, we obtain tungsten trioxide.

**9:23 AM****Advances in Geo-Metallurgical Practices at Mina Cerro Corona Gold Fields La Cima, Peru**

*R. Diaz<sup>1</sup> and M. Diaz<sup>2</sup>; <sup>1</sup>National University of Engineering, Lima, Peru and <sup>2</sup>National University of San Agustin, Arequipa, Peru*

The ore at Cerro Corona is extremely complex in hardness and metallurgical performance. A very thorough understanding of the ore characteristics and blending methodologies was the only way to improve plant performance. The Geo-metallurgical team (Geology - Mine and Plant) works very closely to design the ore blending process before being fed to the plant. This paper covers the effort and results of the Geo-metallurgical program at Cerro Corona.

**9:41 AM****Peru Mining and Waste Deposits – a review on standards and requirements**

*M. Villavisencio; Knight Piesold Consulting, Lima, Peru*

Mining in Peru has booming over the last 20 years. New and large mining operations have been established in addition of existing ones. New and major Tailings and Waste Rock Facilities, as well as Heap Leach Facilities have been designed, built and abandoned. The present paper focus on review pass and current standards for design and operation and closure of these facilities as well as the current permitting requirements from Peruvian Authorities such the Ministry of Energy and Mines.

**9:59 AM****Santacruz Silver: A New Player in the Market**

*A. Prestamo; Santacruz Silver Mining Ltd., Vancouver, BC, Canada*

Santacruz Silver Mining Ltd. owns the Rosario operation which is producing silver, lead and zinc. They are in the process of designing and constructing their second polymetallic mine in Mexico. The author will briefly review how they got here and where they are going in the near future.

**10:17 AM****The Fortescue Story - An Australian Masterpiece**

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

Over a ten year period, Fortescue Metals Group grew from a wild business idea to the world's fourth largest iron ore producer. Starting with two discarded tenements in the Pilbara in 2003 Fortescue began exploring for iron ore. Construction began in 2006 at its first mine, Cloudbreak, and on a 256 km railway and port facilities. Two years later, and only five years after the company was formed, Fortescue shipped its first cargo of iron ore destined for China. In 2014, Fortescue completed a US\$9.2 billion expansion increasing capacity to 155 million

tonnes per annum. The company now operates four mines across its Chichester and Solomon hubs. It operates the fastest and heaviest haul line rail network in the world, where every day 14 trains, each 2.7 km long, transport 33,000 tonnes of iron ore per train from mine to port. Fortescue is a remarkable company, built on a truly great culture. This is a story of sheer determination, teamwork, innovation and a never-give-up attitude.

**10:35 AM**

### **Do Postal Stamps on Minerals and Mining Indicate the Importance of the Industry?**

*D. Malhotra; Resource Development Inc., Wheat Ridge, CO*

The author will present an overview of the importance of mining as illustrated by postal stamps issued worldwide.

**10:53 AM**

15-064

### **Improvement of Ventilation System in narrow vein mines**

*H. Mischo and T. Mueller; Mining Engineering, Technical University Bergakademie Freiberg, Freiberg, Germany*

Mine ventilation is in every underground mine a crucial process to ensure mine safety as well as acceptable working conditions, but on the other hand is also a major cost factor depending on air requirement and air resistance. Due to the fact that the special layout of mines develop over time, ventilation systems changes as well. This may result in complex systems which are suffering severe problems and low efficiency. With attention to the mine safety and costs, ventilation systems have to be controlled repeatedly and optimized continuously to fit changing conditions. The project "Improvement of ventilation systems in narrow vein mines" has been commenced with measuring and data collection in the Bogala Mine, Sri Lanka. This over 150 years old graphite mine consists of about 20 levels. The resulting ventilation system is highly complex and suffers problems like high temperatures and humidity as well as a mixing of fresh and used air on lower levels. To solve these problems and to optimize the system the complete ventilation system had been measured on-site first. The gained data have been used for simulations to develop and select an optimal and cost efficient solution.

**11:11 AM**

### **The Peruvian Mining Scene Following the October 5th, 2014 Elections**

*R. Mucho; Pevoex Contratistas SAC, Lima, Peru*

The recent elections for local and regional authorities in Peru on October 5, 2014, have left a climate of uncertainty regarding support for mining in some of the regions. This has created concern because of the estimated US\$20 billion of investments planned for mining projects within these regions, like Cajamarca, Apurimac and possibly Puno. In contrast, the regions of main mining investment such as Arequipa, Moquegua,

Tacna, La Libertad and Ancash, do not have opposition to mining activities but they experience strong social pressures by the people around these mining projects who believe that mining companies are responsible for solving problems within the surrounding communities, when in fact, this is a government task. The big challenge for the mining sector is to generate a climate of understanding between their companies and the populations of the regions mentioned, that allows the harmonious development of the sector, with the participation of the authorities and all of the stakeholders about the importance of mining in Peru's development.

## **International Mining Education Collaboration Opportunities for the Future**

**9:00 AM • Tuesday, February 17 • 104**

*Chairs: V. Kecojevic<sup>1</sup>, West Virginia University, Morgantown, WV*

*B. Hebblewhite<sup>2</sup>, University of New South Wales, Sydney, NSW*

**9:00 AM**

### **Introductions**

**9:05 AM**

### **International Mining Education - Collaboration Opportunities for the Future**

**Abstract:** Part I This session will cover a panel discussion on successful partnerships, strategic directions on future opportunities and the need to provide leadership and capacity leading into the future. Panelist will briefly present ideas and strategies, followed by discussion among panelists and the audience. The main theme of the session is to address three questions: a) What does the future of the mining industry, and hence its human capital requirement, look like into the future? b) What should we be doing about it in terms of education of mining engineers and collaborative international research c) How is The Society of Mining Professors (SOMP) responding and facilitating these challenges?

**10:15 AM**

**Abstract:** Part II This panel session will be organized by The Society of Mining Professors/Societät der Bergbaukunde (SOMP). The mission of SOMP is to be "a vibrant Society representing the global academic community and committed to make a significant contribution to the future of the minerals disciplines. The main goal of the Society is to guarantee the scientific, technical, academic and professional knowledge required to ensure a sustainable supply of minerals for mankind. The Society facilitates information exchange, research and teaching partnerships and other collaborative activities among its members", <http://www.miningprofs.org/>. Panel participants will include Bruce Hebblewhite (University of New South Wales, Australia); Michael Karmis (Virginia Tech, USA); Vlad Kecojevic (West

Virginia University, USA); Mario Cedron (Pontificia Universidad Católica del Perú, Peru); Jürgen Kretschmann (Technische Fachhochschule Georg Agricola, Germany); Hans de Ruyter (the Federation of European Mineral Programs); Helmut Mischo (TU Bergakademie Freiberg, Germany); Bruce Watzman (National Mining Association, USA); and other industry representatives.

## **Mineral & Metallurgical Processing: Plant Design**

**9:00 AM • Tuesday, February 17 • 708**

*Chairs: N. Ostberg, Freeport McMoRan Inc, Safford, AZ  
T. Doubleday, Freeport McMoRan Inc, Morenci, AZ*

*Sponsored by: Moly-Cop USA, LLC*

**9:00 AM**

### **Introductions**

**9:05 AM**

15-088

### **Carbon Dioxide for pH Control in Mineral Processing**

*D. Tahija; Hecla Greens Creek Mining, Juneau, AK*

Carbonic acid prepared on-site from carbon dioxide gas is widely used in water treatment and increasingly in other industrial applications. It has not seen extensive use in mineral processing but is an attractive alternative to sulphuric acid for pH control, with particular interest in the need to counteract high flotation circuit pH levels caused by cemented backfill. The fundamental chemistry of carbonate solutions as applied to flotation and flocculation circuits is described as well as plant-scale applications. Planned use of carbon dioxide for pH control at Hecla's Greens Creek mill will be outlined.

**9:25 AM**

### **When Laboratory Work and Operating Plant Don't Agree (Part III):Final Plant Design and Process Improvements for the Nicaro, Cuba Caron Ammonia-Ammonium Carbonate Ni Process**

*L. Southwick; L.M. Southwick & Associates, Cincinnati, OH*

A plant was built at Nicaro, Oriente Province, Cuba in the early 1940's using the Caron ammonia – ammonia carbonate leach process to extract nickel for lateritic ores. Operation was generally successful but not economical and was shut down at war's end (Part I). It was restarted in the 1950's with changes to resolve the more serious operational and performance issues (Part II). Operations remained less than satisfactory and included materials of construction (formerly limited by shortages), iron reduction (chemistry, roasters and coolers), ore variability, leach solution strength, nickel recovery, and a variety of

other topics. In Part III the studies of these issues, their findings and implementations of new equipment and procedures will be discussed.

**9:45 AM**

### **DEMETS System Practicality Improvements**

*P. James and M. Baker; Blue Planet Strategies, Madison, WI*

A new DEMETS (BPS's versatile dilute source metal recovery and concentrating technology) stacked electrode cell design configuration has been developed yielding a more compact system and improved maintenance and process support practicality. The new configuration is overviewed along with examples of what a representative DEMETS treatment system of this configuration could look like. The stacked electrode design effectively doubles the electrode use while leveraging familiar tankhouse cell designs and infrastructure – speeding the customized system design process allowing use of common and established tankhouse technology (i.e. cranes etc.) It should be familiar to operators and personnel making operation handoff, maintenance, and labor skill-sets and supply much less challenging. The approach is further expected to yield design and construction savings while lowering risk through existing proven solutions and expertise. It may also enable cost-effective upgrades via retrofitting of existing facilities to achieve DEMETS augmentation.

**10:05 AM**

### **Increasing Sag Mill Capacity at the Copper Mountain Mine through the Addition of a Pre-Crushing Circuit**

*D. Rose<sup>1</sup>, D. MEADOWS<sup>1</sup>, M. Westendorf<sup>2</sup> and D. Tinney<sup>2</sup>;  
<sup>1</sup>Process Technology Center of Excellence, FLSmidth USA Inc., Midvale, UT and <sup>2</sup>Copper Mountain Mine, Princeton, BC, Canada*

Copper Mountain's concentrator was commissioned in May 2011. The circuit consists of a 34' x 20' EGL SAG mill, a Raptor 900 pebble crusher and two 24' x 39'6" ball mills. Each mill is equipped with a 2 x 8500 HP dual pinion drive system. The plant was designed to process 1585 mtpd of SAG feed. From startup, the mill struggled to meet the required production rates. Over time, a major initiative that involved blasting and fragmentation, optimization of the SAG mill in terms of discharge grates, ball size and slurry density, and operation of up to three mobile pre-crushing plants resulted in significant increases in throughput. In parallel, a number of modeling tools, including JK SimMet, were run based on plant benchmarking exercises. After much discussion, consideration, and operation of the temporary mobile pre-crushing plants, a new pre-crushing circuit was designed, constructed and commissioned at the site in August 2014, incorporating a Raptor 2000 cone crusher and associated screening equipment. This paper reviews the history of the original circuit design, the various optimization steps taken and impacts, together with the final pre-crushing circuit and net results.

**10:25 AM****Antapaccay – A Review of Start-up and Operation to Date**

*D. Garcia<sup>1</sup>, J. Villanueva<sup>1</sup>, D. MEADOWS<sup>2</sup> and B. Alegria<sup>2</sup>;  
<sup>1</sup>Concentradora Antapaccay, Glencore, Urbanización Las Gardenias, Peru and <sup>2</sup>Process Technology Center of Excellence, FLSmidth USA Inc., Midvale, UT*

The plant start-up phase of Glencore's 70 000 tons per day copper concentrator near Cusco, Peru started in November 2012 and finished in February 2013. Comminution is achieved by primary crushing, semiautogenous (SAG) milling, and pebble crushing followed by ball milling. The Concentrator is a single line configuration, comprised of one 40 ft. diameter x 22 ft. long (effective grinding length EGL) SAG mill driven by a 24,000 kW gearless drive. The SAG mill feeds two ball mills, each 26 ft. in diameter x 40 ft. long (EGL) with each driven by a 16,400 kW gearless drives. This expansion represents the first Glencore Standard Concentrator, featuring the first 40 ft. SAG mill in Peru which is also the highest power SAG mill in the world, a 6.5 km overland conveyor with gearless drive, the use of an old pit as a tailings dam, and the highest torque tailings thickener in existence. This paper reviews the history, background, and operations start-up, focusing on safety, differences from previous experiences, start-up strategies, technical challenges, main issues, and improvement opportunities.

**Mineral & Metallurgical Processing: Separation: Flotation: Fundamental Aspects****9:00 AM • Tuesday, February 17 • 711**

*Chairs: B. Aksoy<sup>1</sup>, Missouri University of Science and Technology, Rolla, MO*

*A. Sobhy<sup>2</sup>, Missouri University of Science and Technology, Rolla, MO*

**9:00 AM****Introductions****9:05 AM****Fundamental Roles of Nanobubbles on froth stability**

*A. Sobhy<sup>1</sup> and D. Tao<sup>2</sup>; <sup>1</sup>Mining and nuclear engineering, Missouri University of Science and technology, Rolla, MO and <sup>2</sup>Mining Chemicals R&D; China Business Development, SNF-Flomin, Houston, TX*

Froth stability plays an important role in determine the mineral quality and recovery accomplished by a froth flotation process. Froth stability is dependent not only on the frother type and concentration but also on the particle characteristics, associated chemicals and nanobubbles. Theoretical evaluation of the innovative flotation technology was employed using specially designed apparatus to study froth stability, and surface area flux. Nanobubbles significantly impact the froth stability and the bubble surface area flux.

**9:21 AM**

15-138

**An AFM Study of the Adsorption of Collector on Chalcocite***J. Zhang and W. Zhang; University of Arizona, Tucson, AZ*

The adsorption of collector on chalcocite has been studied in situ in aqueous solutions by applying an atomic force microscopy (AFM). The AFM images show that xanthate, such as potassium ethyl xanthate (KEX) and potassium amyl xanthate (PAX), adsorbs strongly on chalcocite mainly in the form of insoluble metal xanthate, which binds strongly with the mineral surface without being removed by flushing with ethanol alcohol. The result clearly shows that the adsorption of xanthate on chalcocite is totally different from its adsorption on chalcopyrite, during which oily dixanthogen is the main adsorption product on chalcopyrite surface. AFM images also show that increasing solution pH to 10 doesn't prevent the adsorption of xanthate on chalcocite much and the result confirms with the fact that chalcocite floats well in a wide pH range up to pH 12 with xanthate being used as a collector. The minor change of AFM images after the injection of a thiol collector suggests that thiol is not an efficient collector for chalcocite, though it works well for chalcopyrite.

**9:37 AM**

15-021

**Particle Size impacts on Reagent Consumption and Recovery***A. Fallaw, L. Moore, Z. Gu, R. Xiong and G. Wang; ArrMaz, Mulberry, FL*

Matrix particle size is a key parameter to a successful separation of the desired metal or mineral from the gangue in a beneficiation plant. The shift in particle size due to matrix change, worn screens or overloading a sizing circuit can lead to higher reagent consumption, while achieving a lower recovery. Understanding how much the particle size shift impacts both of these process performance indicators is crucial in determining plant throughput and planning maintenance activities to optimize the beneficiation process. This case study will demonstrate the extent the matrix particle size characteristics have in a phosphate beneficiation plant.

**9:53 AM****Carrier Flotation of Fine Scheelite With polystyrene (PS)***Y. Hu, R. Liu, W. Sun and X. Chen; School of Minerals Processing and Bioengineering, Central South University, Changsha, China*

This paper studied the carrier flotation of fine size scheelite (0~23 $\mu$ m) with polystyrene (PS) as carriers. The effect of treatment PS and chemical factors including pulp pH and temperature, dosage and species of collectors on carrier flotation were investigated. The flotation mechanisms were investigated by scanning electron microscope (SEM) and particle size distribu-

tion analysis. The results showed that pretreatment of carrier PS using emulsified oleic acid is very important in the carried flotation of fine particle scheelite. Compared with the conventional flotation, the recovery of scheelite increased from 35.05% to 76.37% by using PS carrier flotation. The pulp temperature rise could be helpful to the flotation of fine scheelite. SEM images revealed that a number of fine scheelite adhered to carrier (PS) surface during PS carrier flotation process. However, scheelite particles mainly presented dispersed state and only a few particles agglomerated in conventional flotation. Particle size distribution analysis showed that carrier flotation could significantly increase the particle size of intermediate particles and reach the particle size range of conventional flotation.

**10:09 AM**

### **Effect of Surface and Hydrodynamic Forces on Bubble-Particle Attachment**

*L. Pan and R. Yoon; Mining and Mineral, Virginia Tech, Blacksburg, VA*

In a flotation cell, bubbles and particles are in contact with each other for very short periods of time after each collision. During this time, the intervening film of water must thin and rupture and form finite contact angles. A new force apparatus has been developed to study these events. The results show that the kinetics of film thinning is much faster on hydrophobic surfaces than on hydrophilic surfaces, explaining flotation selectivity. The nanoscale images obtained using the new apparatus show also that bubbles are pulled toward hydrophobic surfaces, forming pimpled films. Both the expedited film thinning and the pimpled film formation are due to the presence of the hydrophobic forces in the wetting films formed on hydrophobic surfaces.

**10:25 AM**

### **Coupled CFD-PBM Modeling in Flotation Cells**

*M. Basavarajappa and S. Miskovic; Metallurgical Engineering, University of Utah, Salt Lake City, UT*

The flow in a flotation cell is highly turbulent and multiphase in nature. Computational fluid dynamics (CFD) and population balance model (PBM) have been successfully coupled for stirred tanks in the past and good match between experimental measurements and numerical results is reported. Flotation cells are characterized by a more complex design of internal parts making modeling them more complicated. Here we have used discrete method usually called method of classes (MC) and moment transformation based quadrature based method of moments (QMOM) to study gas dispersion characteristics in flotation cells. Assuming symmetry, only 120 degree section (one-third volume) of the tank is considered. Using coupled CFD-PBM approach presents a more fundamental representation of physical processes. Results from more computationally intensive but robust method (MC) and computationally cheaper (QMOM) methods are compared and analyzed.

**Mineral & Metallurgical Processing:  
Separation: Leaching****9:00 AM • Tuesday, February 17 • 710***Chair: J. Lee, University of Arizona, Tucson, AZ***9:00 AM****Introductions****9:05 AM**

15-130

**Campaign Testing the Yanacocha Sart Plant  
with High-Copper Feed Solution***M. Botz<sup>1</sup>, G. Guzman<sup>2</sup> and L. Sevilla<sup>2</sup>; <sup>1</sup>Elbow Creek  
Engineering, Billings, MT and <sup>2</sup>Newmont Mining Corporation,  
Cajamarca, Peru*

Newmont Mining Corporation operates the Yanacocha mine in Peru and the gold milling section of the process includes a Sulfidization-Acidification-Recycle-Thickening (SART) plant to remove copper from pregnant leach solution. Since its construction in 2008, the plant has been intermittently operated as needed to remove copper upstream of a carbon adsorption circuit. However, starting in 2015 Newmont expects the plant to operate on a continuous basis in response to higher copper ores that will be processed in the gold mill. In anticipation of this, Newmont conducted a campaign in May 2014 with stockpiled high-copper ore to evaluate performance of the plant with elevated levels of copper in feed solution. Results from the campaign demonstrated the SART plant is capable of efficiently treating high-copper leach solution. During the campaign, SART feed solution copper levels ranged from about 100 to 700 mg/L and copper removals ranging from about 56% to +99% were achieved. The median copper removal efficiency observed during the campaign was about 94%. The primary plant modification determined necessary during the campaign was the need to improve consistency with sulfide dosing.

**9:25 AM****Leaching of Iron with Anaerobic Iron-  
Reducing Bacteria***T. Eisele; Chemical Engineering, Michigan Technological  
University, Houghton, MI*

Reductive leaching of iron by anaerobic bacteria hydrometallurgical process for production of metallic iron from ores and tailings that are not amenable to conventional processing. Microorganisms were collected from an anaerobic bog where natural seepage of dissolved iron was observed. This mixed culture was used to reduce insoluble iron in a magnetite ore to the soluble ferrous state. While dissolution rates were slow, relatively high concentrations of dissolved iron could be reached if sufficient time was allowed. A factorial study of the effects of trace nutrients and different forms of organic matter indicated that the best dissolution rates and highest dissolved iron con-

centrations were achieved using soluble carbohydrate and acetate as the bacterial food source. The ultimate objective is to produce a ferrous iron solution that is suitable for either precipitation as high-grade iron oxide, or direct electrowinning to metallic iron.

**9:42 AM**

### **Beneficiation of Spodumene Ore Into a Concentrate and Further Processing to Produce Battery Grade Lithium Carbonate**

*D. Connelly; Mineral Engineering Technical Services, Perth, WA, Australia*

The demand for high purity battery grade lithium carbonate is expected to grow significantly with the development of electric motorcycles, cars and other devices. The mining and processing of spodumene involves a number of challenges in order to achieve a high grade and recovery with minimal impurities. This paper discusses the value adding step of processing of this spodumene through the traditional sulphuric acid route and the challenges involved in achieving battery grade lithium carbonate. In addition, the advantages and disadvantages of building a lithium carbonate plant in Australia or China are discussed.

**9:59 AM**

### **Operating a subsurface irrigation program across a copper leach pad**

*D. Rucker; HydroGeophysics Inc, Tucson, AZ*

A pilot-scale secondary recovery project using subsurface irrigation was tested on a copper heap in central Arizona. Approximately 40 million gallons of raffinate were injected into a well for several months and it was estimated that 450,000 pounds of copper were liberated based on a sustained grade of at least 1.5 grams per liter. In-situ monitoring revealed a sweep of 45ft from the well, rates of upwards to 400gpm, and tophole pressures around 5-15 psi. Metallurgical parameters derived from solution samples taken from nearby monitoring wells also revealed that measured free acid, pH, and ORP values were indicative of enhanced leaching compared. Based on these results, a program has been developed to apply the subsurface irrigation pad-wide, using the engineering parameters developed from the pilot-scale test. Upscaling will include approximately 170 wells spaced 90ft apart and monitoring will continue to ensure safe operations and optimal leaching. It is estimated that by injecting on 12 wells simultaneously, the leach pad can be effectively flushed within three years.

**10:16 AM**

### **Immobilized Biomining Microorganisms on Bioleaching of Primary Nickel Ore**

*E. Giese, P. Vaz, D. Oliveira and L. Sobral; Center of Mineral Technology, Rio de Janeiro, Brazil*

The acidophilic bacteria *Acidithiobacillus ferrooxidans* is the most studied microorganism for the bio-extraction of metals values out of sulphide bearing ores. The bioleaching is con-

ventionally practiced using percolating heaps where the microorganisms are also in direct contact with sulphide minerals. Biomining bacteria are usually cultivated in bioreactors and their inoculation on ore heaps and dumps are accomplished by suspending those microorganisms in the leaching solution during the irrigation process. This study establishes the use of immobilized cells of *Acidithiobacillus ferrooxidans* as an alternative for inoculating primary nickel ore in a bench scale bioleaching process. The tests using column inoculated with immobilized cells on glass beads showed the same efficiency as compared with conventional method using free cells. The results demonstrated that immobilization of cells proved as being promising to be used on a larger scale as well as it ensure a higher inoculum concentration as its better transport and storage conditions.

**10:33 AM**

### **Leach Heap Stability Under Injection Leaching**

*S. Taylor<sup>1</sup> and D. Rucker<sup>2</sup>; <sup>1</sup>Picacho Associates, LLC, Phoenix, AZ and <sup>2</sup>hydroGEOPHYSICS, Tucson, AZ*

A successful pilot-scale secondary recovery project using sub-surface irrigation was tested on an oxide copper heap in central Arizona. Injection wells were approximately 65 feet deep with injection from the bottom 10 feet through a screened section of the well. Injection head at the bottom of the well was measured at 120 feet (57 psi) and at 55 feet horizontally from the bottom of the well at zero. The maximum injection flow was 375 gpm per well. Wells could be placed in clusters of 4 with 90 feet spacing between wells. Heap stability under injection was important to protect against heap failure and potential environmental contamination. Geotechnical stability analyses are presented that considered set back from the edge of the heap, leached ore material properties, drainage, pore pressures from the injection, location of well(s) and finally acceptable factors of safety.

**10:50 AM**

15-114

### **The Kinetics of Adsorption of Gold, Silver and Copper Cyanide on Activated Carbon**

*A. Ibrado<sup>1</sup> and D. Fuerstenau<sup>2</sup>; <sup>1</sup>M3 Engineering & Technology, Tucson, AZ and <sup>2</sup>Department of Materials Science & Engineering, University of California, Berkeley, CA*

Gold, silver and copper form various complexes with cyanide, of which only the singly charged dicyano form adsorbs appreciably on activated carbon. The adsorption of the dicyano complexes appears to be controlled predominantly by chemical reaction at the surface of a shrinking unreacted core. Metal uptake over time is non-linear, which eliminates control by boundary layer diffusion. The rate of adsorption is not enhanced by a reaction interruption, which suggests the absence of concentration gradients in the pores. Finally, the rate of adsorption increases with decreasing activated carbon size in a manner consistent with the shrinking core model. The results of this investigation accentuate the importance of efficient acid washing of carbon and removing carbon fines from the barren carbon stream. Key Words: gold, silver, copper, cyanide, adsorption, activated carbon, shrinking core model

**11:07 AM****Acid Bake-Leach Process for the Treatment of Enargite Concentrates**

*M. Safarzadeh<sup>1</sup> and J. Miller<sup>2</sup>; <sup>1</sup>Materials and Metallurgical Engineering, South Dakota School of Mines and Technology, Rapid City, SD and <sup>2</sup>Metallurgical Engineering, University of Utah, Salt Lake City, UT*

While enargite concentrates are rich in copper, their refractory nature combined with the high arsenic content of enargite represents major metallurgical and environmental challenges. To tackle these issues, the acid bake-leach process was developed at the University of Utah, which converts the enargite into water soluble phases. The process includes baking the enargite concentrate with sulfuric acid at a low temperature (200 °C); resulting in the conversion of enargite to copper sulfate and arsenic trioxide; copper and arsenic are then released into the solution during water leaching. The chosen temperature is high enough to drive the sulfation reaction but at the same time it is low enough to keep the arsenic in the condensed phase. The experimental results revealed that almost complete Cu and As extraction occurred after 4 h baking at 200 °C, with a sulfuric acid to enargite weight ratio of 4, and particle size P100 = -45 μm, under which conditions no arsenic was lost to the gas phase.

**Mineral & Metallurgical Processing: Separation: Simulation and Modeling****9:00 AM • Tuesday, February 17 • 712**

*Chair: D. Laney, Newmont Mining Corp, Elko, NV*

**9:00 AM****Introductions****9:05 AM****Accelerate Mining Operations Excellence by Investing in Added Resources - Simulation and Optimization**

*L. Wiley and F. Mielli; Schneider Electric, Alpharetta, GA*

Untrained operators and more complex mineral operations have left the mining industry at a huge disadvantage. To correct the current course, a resource investment must be made—to optimize plant conditions and reduce the high rate of employee attrition. This paper will concentrate on new simulation and optimization technologies to quickly and effectively train operators, as well as, run tightly controlled operations safely, profitably, and in compliance with environmental regulations. When coupled together, the realized value of accelerating mining operations excellence will produce maximized returns by improving productivity and efficiencies

**9:23 AM****Flow Simulation in Porous Structures by Lattice-Boltzmann Methods**

*A. Videla<sup>2</sup>, C. Lin<sup>1</sup> and J. Miller<sup>1</sup>; <sup>1</sup>Metallurgical Engineering, University of Utah, Salt Lake City, UT and <sup>2</sup>Departamento de Minería, Escuela de Ingeniería, Pontificia Universidad Católica de Chile, Santiago, Chile*

Porous rock samples are subject to intensive time consuming and costly testing to obtain information regarding flow characterization, which includes permeability determination, oil displacement testing, carbon dioxide sequestration, etc. The availability of high performance computers and x-ray micro CT instrumentation for three dimensional characterization of pore network structures may reduce the need for such testing. Rather, simulation techniques that are well suited to capture interfacial physics at the microscopic level and handle the complex geometry of fluid flow in porous rock can be used to determine permeability, for example. The Lattice-Boltzmann Method is a novel mathematical simulation technique based on fundamental physics that allows solving of the Navier-Stokes equations in a probabilistic bottom-up approach by consideration of the fluid as particles with corresponding momentum conservation equations. A brief review of the LB technique is given followed by an example of water-oil displacement simulations and potential applications in the mineral industry.

**9:41 AM****Flotation Circuit Simulation as a Tool to Evaluate Benefits of Flotation Cell Modernization**

*T. Mattsson, A. Remes and M. Tirkkonen; Outotec (Finland) Oy, Espoo, Finland*

Scope of supply for an existing flotation cell modernization can consist of flotation cell drive mechanism, mixing mechanism, dart valves, cell automation and launders modernization. The objective is to enhance mechanical and metallurgical performance of the flotation cell, and simultaneously increase availability and energy efficiency. To evaluate potential benefits of flotation cell modernization, circuit simulation is proposed. In this new approach, a flotation circuit model is implemented based on kinetic flotation test data from on-site laboratory 'hot flotation' test work carried out with a process sample, thus giving equal feed properties for the model and industrial circuit during the sampling period. During kinetic tests, the floatability kinetics of the main minerals are defined for each flotation stage. The kinetic parameters are then used as a basis to simulate the existing flotation circuit characterized by flotation cell performance with operation specific throughput and solids contents. Finally, the circuit performance achievable with modernized mechanically sound and properly working flotation cells is evaluated on the basis of the modeled and measured performance.

**9:59 AM****Moment Conserved Higher-Order Population Balance Modeling of Gas-Liquid Systems in Flotation Cells***M. Basavarajappa and S. Miskovic; Metallurgical Engineering, University of Utah, Salt Lake City, UT*

In this work population balance model (PBM) is used to study bubble size distribution in flotation cells. Higher order PBM methods based on solution of moment transformed population balance equation (PBE) was proposed by Alopaeus et al. (2006) for coalescence and breakage processes. The approach is based on conserving more than 2 moments of the agglomerate or daughter particles formed as a result of coalescence or breakage and very good improvements in the predictions of size distributions for different forms of breakage and coalescence kernels. Our objective is to use the framework of higher order PBM approach and apply it to gas-liquid flows observed in flotation cells. Pure breakage and pure coalescence processes are studied and the effect of various flow parameters in the kernels is also investigated in different regions of the cells with the assumption of homogeneity in smaller regions in the tank. Combined breakage-coalescence processes are also considered. This approach presents a viable and robust alternative to empirical models.

**10:17 AM****Modeling Froth Stability: Effect of Particle Hydrophobicity***S. Park, W. Sim, K. Huang and R. Yoon; Mining, Virginia Tech, Blacksburg, VA*

Froth stability plays an important role in flotation. As particle-laden bubbles rise along a froth phase, they grow in size due to coalescence, causing bubble surface area to decrease and less hydrophobic particles to drop off. Thus, bubble coarsening provides a cleaning mechanism, which is important for flotation selectivity. In the present work, we have studied the effects of particle hydrophobicity on froth stability by measuring bubble size distribution along the height of froth phase using a high-speed camera. The measurements were conducted in the presence of 35  $\mu\text{m}$  silica particles of varying hydrophobicity. The results showed that froth became increasingly stable with increasing contact angle. At contact angles above 70 degrees, however, froth stability decreased. The experimental results have been analyzed by predicting film thinning rate using the Reynolds lubrication theory, calculating the critical film rupture thickness using a modified capillary wave model, and by estimating bubble loading capacities as a function of contact angle. Based on this approach, a froth model has been developed.

**10:35 AM**

15-092

**Lifecycle Dynamic Simulation for the Mineral Processing Industry**

*Z. Sample<sup>1</sup> and S. Kaushik<sup>2</sup>; <sup>1</sup>MYNAH Technologies, Chesterfield, MO and <sup>2</sup>Portage Technologies Inc., Toronto, ON, Canada*

As mineral processing plants become increasingly complex and sophisticated due to innovations in technology and controls, plant personnel are presented with new challenges making plant operation more difficult than ever. Some of these challenges include worker and equipment safety, operational efficiency, and an increased demand for skilled operators in an industry with an increasingly inexperienced workforce. While there are a variety of simulation software solutions available to overcome these challenges, many focus on steady-state process design, neglecting dynamic process responses. In order to effectively train operators on real-time operational challenges, it is imperative for the simulation to represent the real process. In partnership, MYNAH Technologies LLC and Portage Technologies Inc. have implemented dynamic operator training simulators in the mining and mineral processing industry using modeling blocks which perform their respective comminution and classification calculations using particle size distribution matrices. This solution has been rigorously tested and continues to provide lifecycle benefits to the customer.

**10:53 AM****Simulation of Copper Solvent Extraction Circuits**

*D. Harris; Meridian11 Chemicals, Louisville, CO*

Copper solvent extraction (SX) circuits using oxime reagents are the most economical way to recover the metal for many mines. The high selectivity of the extractant for copper yields high purity electrolyte for the subsequent electrowinning process. The recovery efficiency is dominated by the reagent concentration and its affinity for copper metal. There are tradeoffs for adjusting these factors. Adding additional oxime to the circuit will boost production but at an ever-decreasing benefit. Formulating the reagent with modifiers to change its copper affinity can improve strip efficiency but with a deleterious effect on extraction efficiency. A simulation software was developed to model multiple stage counter-current Cu SX processes. Instead of relying on empirical isotherms, the program uses fundamental chemical equilibria to accurately predict the performance over the typical range of operating conditions. Hence operators and engineers can rapidly optimize their circuits without need for additional laboratory experiments. Reagent concentration, copper affinity, and flow rates can be set where the marginal cost equals the marginal revenue.

## **Mining & Exploration: Building a Safety Culture**

**9:00 AM • Tuesday, February 17 • 702**

*Chair: R. Washnock, Freeport McMoRan Inc., Safford, AZ*

**9:00 AM**

### **Introductions**

**9:05 AM**

### **Building a Safety Culture Focused on Fatality Prevention**

*S. Kramer; Corporate Health & Safety, Freeport McMoRan Inc., Phoenix, AZ*

The safety systems and processes that are successful in reducing incident and severity rates do not prevent fatalities. Developing a culture where the focus is on managing significant risks and implementing critical controls with less reliance on behavior to mitigate these risks is the key to fatality prevention. If we try to do everything well we will do nothing well. We must focus on what is critical to drive our safety success and realize zero fatalities.

**9:25 AM**

### **Providing a Step Change in Safety Culture**

*P. James; Health, Safety and Environment Copper Product Group, Rio Tinto, South Jordan, UT*

Many businesses strive to improve safety performance. To accomplish this, a step change in culture must be provided to achieve sustainable improvement in safety performance. It is imperative to identify the current cultural state and potential barriers to zero harm and then apply effective change management techniques involving both workers and leaders. This presentation will provide an overview of the key factors involved in creating this step change including a strong focus on fatality prevention.

**9:45 AM**

### **Applying the Three Laws of Performance— Minera Escondida: Journey to Zero Harm— November 2002 to March 2004**

*S. Zaffron; Executive Management, Vanto Group, Aventura, FL*

Minera Escondida, located in Chile's Atacama Desert is one of the world's largest producers of copper. In August 2002, a fatal accident occurred and Total Injury Frequency Rate was 23.7 per million man hours worked. World class safety systems installed at the mine were considered too complex and not rigorously being followed by the 5000 person workforce. The President of Escondida created a partnership with Vanto Group to apply Vanto's methodology (previously successfully implemented at mining properties in the U.S., Peru, New Zealand and Australia)

to secure the commitment of management and the workforce to Zero Harm. A 15 month intervention involving over 1600 managers, supervisors, workers, contractors and community members was begun in November 2002 with the top 80 leaders in the organization. This laid the groundwork for transforming the mine's safety culture from one of compliance to one of commitment. The safety procedures went from being something the workers saw as being imposed on them to something they embraced as their own. When the intervention concluded in March 2004, the Total Injury Frequency Rate had been reduced by over 50%.

**10:05 AM**

## **Newmont Mining Vital Behaviors**

*S. Rajapakse; Corporate Health, Safety, Security, Newmont Mining Corp., Greenwood Village, CO*

Newmont's safety performance was considered one of the best in the industry as of 2011 but was still experiencing fatalities and serious injuries. Newmont selected the Influencer Model to help us identify Vital Behaviors that would aid in eliminating our fatalities and serious injuries. The essence of the Influencer Model is that specified results can be achieved by identifying 2 – 4 Vital Behaviors to be taken during crucial moments where decisions one way or the other usually generate vastly different outcomes. These behaviors are encouraged by strategies developed in each of the six sources in the model. As of today, over 300 Vital Behaviors have been identified and nearly 18,000 employees have committed to their identified Vital Behaviors that we believe has contributed to an over 40% decrease in our TRAFR rate in the last 2 years

**10:25 AM**

## **Teck's Health and Safety Journey**

*B. Kelly; Teck Resources Ltd., Vancouver, BC, Canada*

Achieving high performance in occupational health and safety is a function of developing great safety leadership at all levels, building a just culture of care and responsibility, and implementing enabling, fit-for-business systems to help sustain efforts on all fronts. First launched in 2009, Courageous Safety Leadership (CSL) is a values-based approach to safety. The goal of CSL is to empower every employee to be a safety leader and to take a central role in building a culture of safety throughout the company. A supporting High Potential Risks and Controls (HPRC) Strategy is currently rolling out across our operations as we continue our journey in achieving a balance between developing our culture, leadership and enabling systems to identify and effectively control those activities in the business that have the greatest potential to harm our team. A balanced safety system not only requires excellent technical programs, it requires that we build a culture where every employee has the courage, the leadership and the commitment to put safety at forefront of their beliefs attitudes and actions so that we can achieve our vision of Everyone Going Home Safe and Healthy Every Day.

**10:45 AM****Mitigating Fatigue Risk Through Technologies and Safety Culture Solutions***T. Dawson; Safety Services, Caterpillar, Peoria, IL*

Fatigue is a leading contributor to 35 - 40 percent of industry incidents and surveys of employees working non-traditional hours demonstrate that nearly half of the population nods off while working at least once per week. This stark reality has driven the development of programs, systems and technologies that deliver valuable information about the conditions under which employees operate. However, few companies are equipped to leverage the data in a Fatigue Risk Management System that touches all the influencers of a safety culture to deliver safer work conditions and improved performance. Under the right circumstances and with special focus on supporting its implementation, fatigue-detection technology can strengthen the safety culture. Further, the continuous improvement aspect of a comprehensive fatigue risk management system relies in part on the data and feedback gathered as part of the technology data stream. The presentation will include an overview of the sources and risks of fatigue, a proven process for incorporating fatigue technology into the workplace and case studies to show both positive and negative outcomes of implementation.

**Mining & Exploration: Geology: Mineral Deposits I****9:00 AM • Tuesday, February 17 • 705***Chairs: R. Diaz, Maptek  
T. Wakefield<sup>2</sup>, AMEC, Reno, NV***9:00 AM****Introductions****9:05 AM****Selective Mining Implementation at AngloGold Ashanti's Cripple Creek and Victor Gold Mine***J. Brown; AngloGold Ashanti Colorado Corp., Victor, CO*

The Cripple Creek gold mining district is a 31 M.A. alkaline diatreme intrusive complex. Gold mineralization occurred after the diatreme emplacement along the margins of intrusive dikes and sills. Historic underground mining produced ~21 million ounces of gold targeting high grade veins. Current open pit operations produced ~4.5 million ounces of gold; all of which has been processed through a valley leach facility (VLF). As part of Mine Life Extension 2, a bulk flotation mill is under construction with a scheduled completion of late 2014. The mill is scheduled to process two million tons per year; all from open pit operations. Implementation of selective mining began in early 2013. Extraction of high grade mill ores with VLF ores must occur in-sync as to not hinder production. Reverse circulation drilling is utilized for ore body definition. Ore bodies containing required mill qualities such as tonnage, grade and recovery are scheduled for extraction. Mill ores are selectively blasted separate from

VLF production in an effort to mitigate dilution. Reconciliation of designed ore bodies for blasting accuracy, tonnage, and grade are completed using pre and post scans of the ore body.

**9:25 AM**

### **Managing Slope Instabilities in the Wild Horse Extension Pit, Cripple Creek & Victor Gold Mining Company, Cresson Project, Victor, Colorado**

*E. Munroe; Cripple Creek & Victor Gold Mining Company, Anglogold Ashanti (Colorado) Corp. Company, Victor, CO*

The southern end of the Wild Horse Extension (WHEX) Pit contains historical underground workings, a lithological setting, and dump design which is unique to the mine site. In this context, a regressive slope failure is being managed through pit design alterations and tailored safe digging practices. Slope movement is triggered by blasting rind shots proximal to the failure area, excavating the shot material from the toe of the failure, or increasing pore water pressure. Excavation of material is predicated on threshold movement data collected and analyzed from prisms and slope radar. Typical movement of the slope has been 0.5-2 inches/day while acceleration up to 25 inches/day has been recorded due to the above listed reasons. The slope failure vector, determined through prism data with supporting movement detected by the slope radar unit, indicate the slope failure will pinch down as mining excavation progresses to deeper bench levels. Continual understanding of the slope failure geometry relative to the pit slope design and geotechnical mapping data will allow attainment of the design depth through safe slope management practices.

**9:45 AM**

15-084

### **Mineral Deposits Associated with Tertiary Alkaline Igneous Rocks in New Mexico**

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

Lindgren (1933) defined a belt of alkaline-igneous rocks associated with large quantities of Au and REE that extends from AK and BC southward into NM, TX and eastern Mexico. The North American Cordilleran alkaline-igneous belt since has been exploited for numerous types of deposits. In NM, Mid-Tertiary alkaline to calc-alkaline rocks are found with 7 types of deposits in these districts: epithermal/mesothermal veins, Au-bearing breccias/veins ( $\pm$ Te), Cu/Au/Mo porphyries, Cu/Pb/Zn and Au skarns, Fe skarns, Au placers, and Th-REE veins. Some of NM's largest Au and REE deposits are found within this belt. Their origin is not well understood, but a compilation of new data (age dates, isotopic and chemical analyses) allows for a better understanding. The diversity of igneous rocks and associated mineral deposits along this belt suggests that this region is characterized by highly fractionated and differentiated, multiple pulses of magmas and involves both upper mantle and lower crustal sources. Once magmas and metal-rich fluids reached shallow levels, local structures and wall rock compositions determined distribution of and final style of intrusions and resulting mineral deposits.

**10:05 AM****Lubambe Extension - Updated Mineral Resource Estimate***D. Reid; AMEC, Reno, NV*

The Lubambe Extension Deposit is situated in the Copperbelt Province of Zambia, located 8 km southeast of the underground Lubambe copper mine. Various drill programs were conducted in the area since the 1960s, and the initial resource estimate was completed in 2013. A selected mineralized zone (SMZ) was determined within each hole based on a 1% copper grade over a minimum down-hole length of 3 m. These intervals were used to construct triangulations of the upper and lower surfaces of the SMZ mineralization. The assays within the SMZ for each drill hole were composited into a single composite assay that was used for grade estimation. The mineral resource model was constructed using Vulcan Software. Estimation of metal grades, true thickness and dip was completed using Inverse Distance. The estimated dip and true thickness within each block was used to determine vertical thickness and tonnage present within each block. The Lubambe Extension Area Mineral Resource is tabulated using a 1.5% Cu cutoff grade and a minimum true thickness of 4 m. The Mineral Resource is tabulated by Indicated and Inferred classifications.

**10:25 AM****Estimates of the lost Endowment of the Arizona Strip Uranium District, Northern Arizona***E. Spiering<sup>1</sup> and P. Hillard<sup>2</sup>; <sup>1</sup>Exploration, Quaterra Resources Inc., Vancouver, BC, Canada and <sup>2</sup>Exploration, Metamin, Kanab, UT*

In January 2012, the DOI withdrew from mineral entry one million acres of the Arizona Strip uranium district for 20 years. In April, Quaterra, together with several local counties, filed a lawsuit in District Court alleging that the Secretary did not address scientific controversies related to the withdrawal. The most significant was the size of the endowment; a paramount factor in determining all impacts of the action. The EIS used the paucity of published estimates to reduce an endowment of world class importance to insignificance. Preliminary conclusions and exaggerated impacts were used to justify the withdrawal decision even before publication of the final report. This presentation will present two uranium endowment estimates based on past exploration results and USGS publications to provide lawmakers an understanding what the US has lost through the Secretary's action. One estimate will include a study of the blind deposits. The work will also provide the regional information regarding mineralized breccia pipes in the Grand Canyon; an exposure through the center of the district that has been ignored by any study to assess the mineral potential of the surrounding region.

**Mining & Exploration: Operations:  
Hardrock Underground****9:00 AM • Tuesday, February 17 • 703***Chair: D. McDoniel, Nevada Copper, Yerington, NV***9:00 AM****Introductions****9:05 AM****A Comparison between Traditional Timbers  
and Rescue Struts for Mine Rescue Ground  
Control***A. Ahnhut, K. Jennings, A. Robles and J. Torma-Krajewski;  
Colorado School of Mines, Golden, CO*

Timbering has been the primary ground support method in the mining industry since the 1500s. This study compares the traditional method of timbering with that of Paratech Rescue Support Systems as it pertains to temporary ground support in the case of mine emergency response. The study, conducted at the Edgar Experimental Mine in Idaho Springs, CO, was intended to determine the strengths and weaknesses of each method including total time for installation, total support strength and ease of use. The cost of each option was also investigated. The emergency response sector of the mining industry is at a turning point and this presents a great opportunity to take a look at some of the technology that is currently in use by the fire service for stabilization of vehicles and collapsed structures and determine if it would be an option to integrate into modern mine emergency response.

**9:25 AM****Spontaneous Combustion Problems  
and Treatment at one Lead and Zinc  
Underground Mine***F. Yang<sup>1</sup> and J. Tien<sup>2</sup>; <sup>1</sup>Mining and Nuclear, missouri university  
of sci.&tech., Rolla, MO and <sup>2</sup>mining engineering, Monash  
University, Clayton, VIC, Australia*

Spontaneous oxidation or combustion is a kind of exothermic chemical reaction between sulfide ore constituents and oxidants. And the heat release rate by exothermic process exceeds that of heat loss or dissipated. Several sulfides such as pyrite, marcasite, sphalerite and galena coexist at this underground mine. Their geological and crystal relationship in the original deposit was introduced. This paper discusses the problem of self-heating or spontaneous combustion based on field observations and investigations of both underground sulfide ores and aboveground concentrates. A large amount of pyrite and marcasite exist in the strati form mineralization zone. Marcasite is a major sulfide in both mineralization zones. While the quantity of pyrite is relatively lower. Marcasite and pyrite, they are of polymorph for each other. After X-ray micro-analyses, the compositions of Marcasite and pyrite are as follows: S 53.33%, Fe

46.67% and S 54.03%, Fe 45.97% respectively. And lead concentrate oxidize easily and smokes generated in this process only, while zinc concentrates do not.

**9:45 AM**

### **LHD Automation and Real Time Machine Tracking - Improving Production Optimisation and Safety in Large Block Cave Operations**

*R. Yates; Engineering, Royal Melbourne Institute of Technology, Melbourne, QLD, Australia*

A case study in the application of LHD Automation and the development of high precision real time production fleet tracking to improve the accuracy of underground machine tracking and production reporting whilst improving operator safety. Author has worked in collaboration with several mining operations to implement and evolve underground mining technology products to improve operator safety through remote operation of the production LHD fleet. The technology has been integrated with a fleet management solution to ensure optimal data accuracy to improve caving compliance reporting, operator traceability and quantify opportunities for production optimization. This paper will discuss the application of these technologies and the improvements realized in case studies.

**10:05 AM**

### **Electric Loading and Haulage Equipment as Means to Improve Viability of Underground Metal Mining at Great Depths**

*J. Paraszczak<sup>1</sup>, E. Svedlund<sup>2</sup>, K. Fytas<sup>1</sup> and M. Laflamme<sup>1</sup>;  
<sup>1</sup>Mining, Metall., Mat. Engrg, Université Laval, Quebec City, QC, Canada and <sup>2</sup>Atlas Copco Rock Drills AB, Örebro, Sweden*

Metal mining at great depths is associated with a high demand for fresh air required to cool down mine openings, evacuate noxious gases and contaminants, as well as to provide sufficient amounts of oxygen for miners. Diesel powered load-haul-dump (LHD) machines, trucks and other mobile equipment used extensively by modern mines not only emit exhaust gases and diesel particulate matters (DPM), but constitute also an additional source of heat. As mine regulations get more stringent with regard to air quality, the use of diesel engines has an increasingly adverse impact on ventilation costs. In this context, this paper examines electric drives as possible alternatives for diesel power trains. They are reviewed with regards to their principles, required infrastructure, as well as technical and operational issues. Their practicality and economic viability are also addressed. Moreover, their benefits and potential for implementation in the conditions of deep metal mines are discussed. The paper concludes with a resume of current and short-term potential of electric loading and haulage equipment as alternative to diesel-powered vehicles in deep metal mines.

10:25 AM

## **New Afton Underground Ore and Waste Handling System**

*C. Campbell and S. Kozoriz; Mine Operations, New Gold, Kamloops, BC, Canada*

New Gold's New Afton mine, located 8 km west of Kamloops, British Columbia, started production in 2012 as an 11 000 tonne per day block cave mine, making it the highest tonnage underground hard rock mine in Canada. Since that time, New Afton has steadily increased production to 13 000 tonnes per day. Continuous improvement of throughput from the underground production system at New Afton has included certain expected challenges. Segregation of underground ore and waste material, developing new and innovative ways to clear tramp steel during the gyratory crushing process, and establishing a high availability crush and convey system are a few of the many techniques that New Afton has used to progress to best-in-class standards for efficiency in production. As New Afton looks to the future, other efforts are underway to further increase production such as increasing crush and convey system utilization, and debottlenecking of the underground production systems.

## **Mining & Exploration: Technology: Information Systems Integration for Decisions Support**

9:00 AM • Tuesday, February 17 • 707

*Chairs: V. Tenorio<sup>1</sup>, University of Arizona, Tucson, AZ  
S. Dessureault<sup>2</sup>, University of Arizona, Tucson, AZ*

9:00 AM

## **Introductions**

9:05 AM

## **Addressing Mine Fuel Management Challenges with Cloud and Wireless Technologies**

*F. Mielli<sup>1</sup> and K. Short<sup>2</sup>; <sup>1</sup>Schneider Electric, Alpharetta, GA and <sup>2</sup>Schneider Electric, Casper, WY*

In some mining operations the fuel costs can be more than 10% of the overall operational expenditures and very often several operations lack visibility regarding their fuel usage: Overall fuel consumption, real time monitoring, reconciliation, asset management (consumption by asset), lack of performance indicators (or mine benchmarking), loss of data and even fraudulent activities. The objective of this presentation is to show an integrated approach using wireless sensors, software technologies and smart telemetry to monitor and track fuel inventories, asset consumption, purchases and fuel dispensed - Also delivering rich information to help management to take the right decisions regarding the optimized use of the fuel

**9:25 AM****Software Integration within Mining Industry - Keeping Consistency and Technical Integrity***R. Witucki and F. Mielli; Schneider Electric, Alpharetta, GA*

Mining industry is IT driven. Several software and applications are required to make the mining business running: Geology, Planning, Scheduling, Fleet, Laboratory, Inventory, Stockpile Management, Automation - Just to name a few - and those applications are constantly being fed and exchanging data among them. The main challenge of this myriad of software and applications is to create a streamline architecture among them to avoid chaos: data duplication, multiple interfaces and complexity. This presentation will tackle best practices about software integration and provide some example of mining IT software architectures.

**9:45 AM**

15-041

**Using Simulation to Quantify Uncertainty in Ultimate Pit Limits and Inform Infrastructure Placement***M. Deutsch, E. Gonzalez and M. Williams; Maptek, Lakewood, CO*

There is uncertainty in ultimate pit limits due to geologic variation and unpredictable economic landscapes. In this work we show how this uncertainty affects the ultimate pit and how it can be analyzed to improve the mine planning process. A stochastic framework using geostatistical simulation and parametric analysis is used to model the effects of geologic and economic variation on ultimate pit limits and overall project economics. This analysis is made possible by a new, highly efficient pit optimization implementation which can be automated and set up to calculate ultimate pits for hundreds of different scenarios in a matter of hours. Quantifying ultimate pit uncertainty early in the mine planning process allows mining engineers to make informed decisions regarding infrastructure placement, and to mitigate the possibility of incurring substantial costs relocating critical mine facilities.

**10:05 AM****Asset Optimization: Calming Cloud over the Supply Chain***O. Bascur<sup>1</sup> and M. Halhead<sup>2</sup>; <sup>1</sup>OSIsoft, LLC., Houston, TX and <sup>2</sup>AngloAmerican, Johannesburg, South Africa*

The Metals and Mining industries continue to be challenged by deflated commodity prices, increased energy costs, decreased quality of the ores and expanded regulatory requirements. In an effort to offset these headwinds, leaders in these industries are now starting to adopt comprehensive information strategies to improve operational efficiency and business performance. In many situations, all partners in a business collaboration – such as joint ventures, contract manufacturers, expert service providers, and operations and maintenance companies – need access to production and asset data. When all partners have access to

the real time data, each can plan ahead for equipment maintenance or for scheduling the delivery of critical components. PI Cloud connect provides all parties a secure way of sharing data between their respective PI Systems without having to deploy point to point VPNs. This presentation will share examples of how mining and mineral processors have adopted new strategies such as self-serve business intelligence, cloud computing and internal/external collaboration. Mine and mill asset availability and drastic reductions in operating costs examples will be presented.

**10:25 AM**

### **Data Mining Applications in Mine to Mill Optimization**

*M. Erkayaoglu and S. Dessureault; Mining and Geological Engineering, University of Arizona, Tucson, AZ*

Mine to Mill optimization is a common objective for hard-rock mines. Efforts within the drilling and blasting processes are important while challenging to quantitatively link performance to downstream processes such as grinding or leaching. Operational data collected is found in databases of highly varying structures and levels of granularity. Hence, mine to mill is ideally suited for advanced data analytics. In order to model drilling and blasting processes, an integrated layer of data where transactional and process based data lives is needed. Data mining is a tool that relies on integrated data structure. This structure is used for pattern discovery within the data itself. Relationships that remain unquantified or that are based on simplified deterministic equations can now be revisited by data mining that rely on vast amount of data. Equations based on a limited set of data could be improved by using data mining. This research is focused on creating new variables and procedures leveraging data mining concepts to determine more predictable fragmentation and grinding performance using an integrated data set at a copper mine that has both run-of-mine-to-leach and a SAG mill.

**10:45 AM**

### **Integrating Ore Control Process for Decision Making Updating Mine Planning Systems**

*B. Perez<sup>1</sup> and J. Herrera<sup>2</sup>; <sup>1</sup>Mine Engineering, Newmont Mining, Sumbawa, Indonesia and <sup>2</sup>Information technology, Newmont Mining, Denver, CO*

Open pit operations rely on the Ore Control Systems (OCS) to distinguish ore from waste by providing dig polygons to the production fleet. This paper documents specific aspects of a typical ore control system and discusses the application of newer and tighter integration with fleet management systems and/or drill holes databases. The OCS consists of several components; its main goal is to separate economical material from non-economical material. The new OCS components today uses computers and data management in several steps beyond the traditional delimitation of different materials polygons based on grades characteristics. The new OCS can provide more information and stored in its databases with a new integrating approach. Databases exchange information and add more valuable data along the processes for Blasting, Fragmentation and Fleet management to take better decisions for the mined mate-

rial and saving cost and improving results when uses a data warehousing techniques. This paper focuses more on integration and improves to the OCS.

## **Mining & Exploration: Technology: Reliability & Availability, Are You Getting It?**

**9:00 AM • Tuesday, February 17 • 704**

*Chair: M. Armstrong, Caterpillar, South Milwaukee, WI*

**9:00 AM**

### **Introductions**

**9:05 AM**

15-005

### **Genetic Algorithms applied in fleet maintenance analysis: case studies with seven underground scoop trams**

*N. Vayenas, S. Peng and A. Farah; School of Engineering, Laurentian University, Sudbury, ON, Canada*

Nick Vayenas, Sihong Peng and Anis Farah, Laurentian University, Sudbury, Canada While Genetic Algorithms (GAs) have been widely adopted in ore grade estimation, mine design and production scheduling in mining, reliability and maintainability analysis of mining equipment using genetic algorithms has been a relatively new research area. This paper presents an application of GAs using case studies with seven underground scoop trams whose maintenance records have been collected over a period of 12 months from a mine in Canada. Based on the assumption that various factors that contribute to machine failures resemble biological evolution process, the authors have developed a PC software application called GenRel which adopts GAs in its programming logic. In this study, the authors use historical maintenance data into GenRel in order to predict future maintenance characteristics of mining equipment in a time period of three months. Then, the predicted maintenance characteristics are compared to the actual maintenance records in the same time period. A statistical study is then used to examine the similarity between the predicted data and the recorded data.

**9:25 AM**

### **Use of Apps and i-Technologies to Improve Equipment Reliability**

*K. Pickens<sup>1</sup>, T. Hermanson<sup>3</sup> and J. Forman<sup>2</sup>; <sup>1</sup>Process Improvement, Arch Coal, Wright, WY; <sup>2</sup>Process Improvement, Arch Coal, Charleston, WV and <sup>3</sup>Process Improvement, Arch Coal, Wright, WY*

With a constant need to focus on improving cost and equipment reliability, the need to be efficient becomes more and more important. Technology offers endless opportunities to improve

efficiency in the field but can also bring challenges. Utilizing internal IT services to create custom applications on handheld devices such as iPads or iPods that can be used for more thorough reporting and inspections by technicians in the field can help improve efficiency and reliability at a low cost. Custom applications can be used to improve efficiency of the technician as well as coordination and communication between departments. This discussion will focus on a lube and fuel app being utilized at the Coal Mac Mine in West Virginia to better track fueling of mobile equipment as well as create awareness of pieces of mobile equipment overconsuming lube and other fluids. In addition, other mines within Arch have capitalized on this same idea, such as the Black Thunder Mine in the Powder River Basin, where the lube app is being updated for heavy equipment components and iPads/iPods are being utilized to do more thorough inspections on pieces of equipment pre-PM and during PMs.

**9:45 AM****Quality affects Availability - too, obviously?**

*M. Kressner<sup>1</sup>, M. Pohl<sup>2</sup> and D. Slowik<sup>1</sup>; <sup>1</sup>Project Development, TENOVA TAKRAF, Lauchhammer, Germany and <sup>2</sup>Engineering, TENOVA TAKRAF, Leipzig, Germany*

The importance of “quality” seems missing from customers focus and not a pertinent enough factor in the stage of the investment project. Beyond clear customer preferences for quality and reliability it can be observed an absence of attention to quality features related to the equipment design & layout in favor of lowest CAPEX in a majority of investment projects. Mostly the final design & layout suffers from a lack of capacity reserves or has vulnerability to changing capacity requirements or exhibits poor equipment handling ability or high maintenance efforts – just mentioning some of the problems. The economic balance between the best and the “good enough” solution varies from case to case but is usually not a focus of the budgeting and bidding process. The presentation considers differences in the definition of availability and demonstrates technical solutions as well as consequences for operation behavior, maintainability and reliability for selected continuous operating mining and material handling equipment.

**10:05 AM****How Hoist Brake Improvements Increased Electric Rope Shovel Availability**

*M. Evans; ERS - DGL Product Group, Caterpillar Global Mining, South Milwaukee, WI*

In January 2014, a new Dynamic Heavy Duty Hoist Brake (with Optional Smart Controller) was released into the field to increase brake life cycle under full load stopping conditions for Electric Rope Shovels. This paper will discuss the problem faced, solution implemented, and how it increased reliability / availability of the machines for the customer.

**10:25 AM****Delivering Availability with Work Management***J. Haas; Maintenance, BHP Billiton, Farmington, NM*

To deliver high quality preventative maintenance and increase availability a strong work management program will ensure the execution of the right work at the right time in a safe, repeatable, predictable and cost-effective manner.

**Mining & Exploration: Technology: Technology Development and Implementation in Rock Mechanics and Ground Control****9:00 AM • Tuesday, February 17 • 706***Chairs: T. Jones<sup>1</sup>, NIOSH**K. Perry<sup>2</sup>, University of Kentucky, Lexington, KY***9:00 AM****Introductions****9:05 AM**

15-090

**A New High Force and Displacement Shotcrete Test***L. Martin, C. Clark, J. Johnson, M. Stepan, S. Iverson and D. Benton; CDC/OMSHR/SRL, Spokane, WA*

Determining the energy absorbing characteristics of reinforced shotcrete used as skin control between rock bolts is a key element in designing support that can protect miners through large ground displacements driven by creeping ground or more suddenly, by seismic loading. The energy absorbing characteristics of support systems utilizing reinforced shotcrete in combination with other support elements such as plates, bolts and various configurations of shotcrete that utilize mesh and polyfibers are largely unknown from a systems standpoint because of the difficulty in testing assembled composite systems. Bi-axial testing of large scale reinforced shotcrete panels can provide insight into the load capacity and toughness of these multicomponent engineered support systems. With this in mind researchers developed a high energy high displacement (HEHD) stiff frame test structure and tested a number of reinforced shotcrete panel configurations. Design of the HEHD bi-axial test machine and results of large scale panels of various constructions (ranging from unreinforced to reinforced with encapsulated wire mesh and polyfiber) are presented.

**9:25 AM****Surface support system at the Leeville Underground Mine***C. Sun; Engineer, Newmont Mining Corp, Carlin, NV*

Surface support in a rock drift may be supplied shotcrete, fiber shotcrete and spray-on polymer in combination with rock bolts or dowels, steel sets, wire mesh or various types of reinforcement mats. Such support techniques are often used interchangeably or in combination for a variety of ground support roles. They provide a flexible support that takes advantage of the inherent rock strength but that can be stiffened simply and quickly by adding bolts, wire mesh and/or shotcrete. In addition, wire meshes provide a simple template by which to judge the thickness of shotcrete. For other situations wire mesh or reinforcement mats have proven to successfully arrest and hold local raveling until sufficient shotcrete can be applied to knot the whole system together and hold it until the shotcrete attains its strength. To determine the appropriate surface support system in Leeville underground mine, lab experiments and field investigations were conducted in recent years. Based on these research and investigation the appropriate surface support system was found and applied in the very weak ground conditions at the Leeville underground mine.

**9:45 AM****Calibration of displacement data from Multi-Point Borehole Extensometers to time-dependent numerical models in 3DEC***R. Thareja and R. Kallu; Department of Mining and Metallurgical Engineering, University of Nevada Reno, Reno, NV*

Many Nevada gold deposits are found in highly fractured and faulted host rock with RMR ranging from 10 to 50. Various ground control design issues in weak rock masses are faced by most underground mines operating in Nevada. Numerical models complement field observations, instrumentation techniques, and testing by providing a better insight into the fundamental behavior and response of weak rock mass and its interaction with support systems. It facilitates development of a better design methodology and guidelines for excavation span and support design. MPBX arrays were installed in underground excavation and the displacements at MPBX nodes were observed for duration of 18 months at two different sites. Numerical models were designed to take into consideration the effect of jointing using discrete fracture network (DFN) and rock bolts in 3DEC. Calibration of the numerical models was done to the monitoring data from MPBX arrays. Creep studies were performed on numerical models to achieve a time dependent calibration with the MPBX data.

**10:05 AM**

15-040

**Correlation of Newly Detected Mining Induced Seismicity with Subsidence in a Wyoming Mining District**

*D. Chambers<sup>1</sup>, J. Wempen<sup>1</sup>, M. McCarter<sup>1</sup> and K. Pankow<sup>2</sup>;  
<sup>1</sup>Mining Engineering, University of Utah, Salt Lake City, UT and  
<sup>2</sup>University of Utah Seismograph Stations, Salt Lake City, UT*

The EarthScope Transportable Array (TA) of broadband seismometers ([www.usarray.org](http://www.usarray.org)) was deployed across southwest Wyoming from November 2007 through May 2009. During this time period the Array Network Facility (ANF, [anf.ucsd.edu](http://anf.ucsd.edu)) detected and located a total of six seismic events near the trona-mining district. This lack of seismicity is atypical compared to coal mines employing similar mining methods. In this study, eighteen months of continuous seismic data from several nearby TA stations are reexamined using conventional and correlation-based methods to detect seismic events. Waveform cluster analysis and epicentral locations are used to discriminate between mining induced seismicity (MIS) and seismic energy generated from surface blasts at nearby coal mines. The locations and magnitudes of the 143 newly detected MIS events are compared to regional subsidence as measured by Differential Interferometric Synthetic Aperture Radar (DInSAR).

**10:25 AM****Ground Support Strategies used at Underground Gold Mines in Nevada**

*S. Warren<sup>1</sup> and R. Kallu<sup>2</sup>; <sup>1</sup>Mining Engineering, Univ of Nevada-Reno, Reno, NV and <sup>2</sup>Mining Engineering, Univ of Nevada-Reno, Reno, NV*

Ground conditions at underground gold mines in Nevada range from good to extremely poor and implementing the most appropriate ground support can be challenging. Typical ground support elements include rock bolts, metal straps, wire mesh, and shotcrete. This presentation summarizes support strategies, design, and implementation observed from research at several operating underground gold mines in Nevada. Insight into the performance of various combinations of support elements and sequencing in a variety of ground conditions is also provided.

**10:45 AM****Application of Refraction Microtremor (ReMi) for predicting changes in geologic structure in an underground mine**

*C. Barnard and R. Kallu; University of Nevada, Reno, Reno, NV*

A study was conducted to determine the applicability of Refraction Microtremor (ReMi) in order to predict changes in geologic structure in an underground mine. The data was collected at Turquoise Ridge Joint Venture, and was analyzed using the SeisOpt® ReMi™ (© Optim, 2014) software. In order to determine whether the changes seen actually exist, shear wave velocities were measured in location of known geologic changes. In addition to changes in geologic structure, the shear

wave velocities were compared with the Rock Mass Rating (RMR) of several locations. These values were then compared with previous published values on RMR and shear wave velocity correlation. Based on the data collected, a determination was made as to whether ReMi can effectively be used to determine change in geologic structure in an underground mine, as well as, whether published correlations between shear wave velocity and RMR hold true.

## **Research: Next Generation Innovation in Mining Industry**

**9:00 AM • Tuesday, February 17 • 507**

*Chairs: A. Samal<sup>1</sup>, Rio Tinto Exploration, Riverton, UT  
R. Gilbert<sup>2</sup>, Freeport-McMoRan, Safford, AZ*

**9:00 AM**

### **Introductions**

**9:05 AM**

### **A Practical Approach to Technology Development**

*R. Gilbert; Technology, Freeport-McMoRan Inc, Phoenix, AZ*

Providing workable, near-term solutions to production challenges has been Freeport-McMoRan's approach to technology development. R&D that leads to flashy gadgets or abstract concepts has yielded to the more practical nuts-and-bolts approach of delivering near-term solutions to everyday challenges. FMI has made significant strides in advancing concentrators, stockpile leaching, concentrate pressure oxidation, haulage safety, material characterization, and electrowinning. Several technologies are summarized in this paper

**9:20 AM**

### **The New Face of Mining – Industry-University Research Partnerships**

*M. Poulton; Department of Mining and Geological Engineering, Tucson, AZ*

The Lowell Institute for Mineral Resources (IMR) draws on faculty with deep domain knowledge to forge sustainable solutions that impact the entire mineral resources life cycle. More than 200 faculty and students in 28 disciplines and 11 colleges have worked with 40 companies on more than 100 projects directly benefitting the needs of the global mining industry in the past 4 years. Thematic research areas include health and safety, environment, ore deposit geology, extractive metallurgy, mine operations, geomechanics, social license to operate, indigenous peoples, water, and energy. Faculty involved in the IMR have created or licensed technology to 8 companies. We will review how to structure university-industry research partnerships to produce effective and timely innovations for the mining industry. We will highlight some of the key results and current projects.

**9:35 AM****Innovations in Copper Smelting - from primitive to advance in 30 years***D. George; Processing, Rio Tinto, Technology and Innovation, South Jordan, UT*

Copper smelting was one of the more primitive parts of the non-ferrous industry characterized by dangerous working condition and high toxic gas and heavy metal emissions. In the 1960's Kennecott and others began to research and test techniques to intensify smelting and allow more efficient capture and control of emissions. This work culminated in the development of Kennecott-Outotec Flash Converting which enabled the design and construction of the current highly efficient flash smelting based smelters. This paper will review some of the major initiatives, including some that have failed, and focus on the latest developments that have led to modern smelting technologies that can capture of virtually all of the emissions. A view of future technology opportunities will also be presented.

**9:50 AM****Current and Future Challenges in the Processing of Low Grade and Poor Quality Mineral Resources***P. Somasundaran and P. Patra; 1Henry Krumb School of Mines, New York, NY*

Declining ore grades and quality present multiple challenges to the mineral industry. Low grade and poor quality ores tend to have complex mineralogy, especially gangue minerals, and complex water chemistry and pulp viscosity. Innovations in chemical and processing schemes are needed to address these challenges. The first part of this talk will focus on recent advances made in these areas, and with discussions on a few cases, such as processing of low grade fibrous Ni ores. The second part of the talk will focus on identifying the future trends and research needs for the sustainability of many mining operations. Extent of water consumption and fate of reagents serve as indicators of economic and environmental sustainability. Greener chemicals as alternatives to currently used hazardous chemicals and greener processing flow sheets have been acknowledged as approaches to sustainable processing as well. Some of these aspects will be discussed with examples taken from dewatering of phosphate tailings and the bio-processing routes that are seen as potential solutions to these challenges.

**10:05 AM****US Oil Sands Extraction Process***S. Verma; Processing, US Oil Sands Inc., Salt Lake City, UT*

US Oil Sands Inc. (USO) is developing the PR Spring oil sands deposit in eastern Utah. The initial production rate is 2,000 barrels of saleable bitumen per day. The Run-of-Mine (ROM) ore contains approximately 8-10% w/w of bitumen. The process used by USO is a proprietary and patented process for extracting bitumen from surface-mineable oil sand deposits. It is similar in general concept to the well-known Clark Process. Both methods require the oil sands ore to be mined and hauled to a processing facility for extraction of the bitumen and disposal

of the produced sand tailings. The principal difference between the two processes is that the USO process utilizes an environmentally friendly non-petroleum-based solvent to achieve a high degree of separation from the ore in a relatively low energy extraction process. The resultant clean sand tailings are suitable for disposal back to the mine pit without the requirement of a tailings pond. USO's process also recovers and recycles 95% of its water demand as well as 98% of its solvent demand.

**10:20 AM**

### **Risk assessment using multiple simulations of mine designs on web based cloud computing platform**

*A. Lapworth; CAE Mining Software Ltd, Somerset, United Kingdom*

Open pit mine enterprises are complex systems that depend on multiple parameters all of which vary in time and space with a different degree of uncertainty. The unpredictable nature of these inputs impose a risk to mine owners and shareholders which in the worst case can lead to highly undesirable financial outcomes. This presentation presents a risk assessment tool set and methodology that uses web based cloud computing to enable multiple simulations of mine designs to be rapidly and efficiently executed. The methodology includes generating random sets of prices and costs values within their respective probability distributions. Pit designs are then created to maximize the profit for each set of input variables. Various approaches to analyzing the results to understand the relative risks of projects are discussed. The potential for using the same cloud platform for storing, processing and analysing of mining data for the update of plans in real time are discussed.

**10:35 AM**

### **Safer. Greener. Lower Operating Cost. The Choice to Invest in Performance Enhancing Concepts and Technologies Gets Easier**

*R. Adsero; Current Power Solutions Inc, Houston, TX*

In view of the decade long decline in worldwide mine equipment productivity there is more to do than measure how far and fast we've fallen. With heavy economic pressures and survival at risk, improvements are in progress. Understanding your mines particular situation is critical to making a change for the better. Benchmarking can be a stop along the way to help in knowing where you stand in relation to others operating the same equipment. Another approach is to consider the various technologies and concepts that have helped the most driven innovators among us achieve the best equipment performance possible. With some historical perspective we will discuss a few of these concepts with a particular focus on dragline performance. The less aggressive have not taken advantage of the numerous innovations in mine technology. Today there is overwhelming evidence that adopting these concepts including AC drive technology can and will bring about a step change in dragline operating cost improvement and improved production performance. The economic case is presented.

**10:50 AM****Predictive analytics in enterprise asset management in mining***A. Kumar; Management Consulting, KPMG LLP, Denver, CO*

Mining is asset-intensive with large fleets of heavy equipment and requires large capital investments. In this tough market, the focus is on driving optimal value from the assets enterprise wide. Over years, advancement in fleet management systems involving such capital equipment have provided companies the opportunity to subject operational and financial information to high quality analytics for “predictive decision making” using “big data” leading to possibilities of proactive decision making in asset operations and maintenance processes. This helps find the right balance between ongoing maintenance, capital replacement and overall risk mitigation strategies. Methodology to derive a model for business risk exposure based on health index of assets and probability of failure as well as the consequences of the failure is explored. Risk profile for future periods are then utilized to emphasize on multiple maintenance strategies for different asset classes. Risk mitigation strategies are discussed based on the risk zones generated by constant risk plots. Such models are being utilized for optimization decisions leading to higher profitability of companies.

**11:05 AM****System Integrated Metal Production***M. Reuter; Technology Management, Outotec, Espoo, Finland*

Achieving resource efficient production throughout the metal value is an imperative for society. This paper will discuss resource efficiency in a system integrated manner. It will highlight the role technology and its innovation as well as system optimization and its innovation as key drivers. Integration of water, energy and metal productions systems will be investigated and analyzed, also highlighting the use of digitalization methodologies (e.g. simulation, process control, environmental footprinting, life cycle costing, etc.) to achieve this. Also key to these discussions is among others training of young talent, stimulating innovation at university (also through massive open online courses) and engagement in policy discussions. Examples shown will be based on a wide range of base metal recovery and production while integrating water and energy recovery solutions with the aforementioned. Ultimately we as an industry must show that we know what our resource efficiency baseline is and show how crucial we are to producing the metals and materials that are enabling a resource efficient society. This paper will show how this can be achieved.

## **The Business Case for Standard Guidelines in the Current Mine Operations Environment**

**9:00 AM • Tuesday, February 17 • 109**

*Chair: M. Bartlett, Desert Falcon Consulting, Tucson, AZ*

**9:00 AM**

### **Introductions**

**9:05 AM**

### **Leveraging Technology Standards to Produce Better Operational Tools**

*P. Wan; Teck Resources, Trail, BC, Canada*

Technology has played an ever increasing role in mining operations over the last 30+ years – with wireless networks, fleet management systems and asset health monitoring just some of the technologies seeing broad uptake in the industry. The availability of standards to streamline the development of these technologies has not been consistent across the board, resulting in very different outcomes in terms of speed of uptake and product cost and development timelines. This presentation will provide examples of technologies that have benefitted from the availability of an industry standard – and others that have emerged in the absence of a defining standard. The impact of industry standards will be explored from a number of angles – including commercial, skills requirements/availability, project timelines and product life cycles. The presentation will also explore steps that can be taken by mining companies to participate in the development of industry standards or guidelines through a collaborative, global approach that addresses industry challenges.

**9:25 AM**

### **The Coalition of the Willing: Developing a Unified Display for Large Mining Shovels**

*A. Chapman; Peck Tech Consulting Ltd., Montreal, QC, Canada*

As we move into the 21st century, challenges in mining operations are on the rise with growing scale and operational complexity. Mining operators are faced with complex information delivered by equipment systems that are technology-centric rather than user-centric. The ability to achieve fast and accurate situation awareness (SA) in the face of this data overload is a key factor that allows for effective decision making and information exploitation. Incidents that result in loss of revenue, compromise safety, or even loss of life, which are attributed to human error are often the result of system designs that overload human cognitive capabilities. The solution may be found in the development of a common user interface for shovels, that would prioritize and streamline operators' access to information from onboard their machines. The Global Mining Standards Group (GMSG) has developed a proof of concept, tested it in a variety of settings and is currently working to determine the most effective strategy for further adoption of this concept in the mining industry at large.

**9:45 AM****Impact of Formal Standards on Mining**

*T. Skinner; Global Mining Standards and Guidelines, Calgary, AB, Canada*

The mining industry is continually challenged to become increasingly efficient, productive, cost effective, and safe. There is also a growing recognition for the role that industry standards can play in achieving these objectives. To date, the mining industry has not been a leader in the development and implementation of global standards and there are many benefits. Utilizing standards in our mining industry will greatly benefit the development, integration, and implementation of system products and services provided by industry players. Establishing the use of standards in our mining industry has been a challenge amongst the major stakeholders: the mine operator, 3rd party suppliers, OEMs, and OTMs (Original Technology Manufacturers). This presentation will present the benefits, opportunities, and challenges that industry standards and guidelines can bring to all stakeholders in our global mining industry. It will also present a path forward for an increased effort to support operational excellence with global standards and guidelines, particularly as they apply to operational mining, systems integration, and safety.

**10:05 AM****A Framework for Integrated Operations in Mining and Metals**

*L. Mottola; Flow Partners, Montreal, QC, Canada*

It is generally accepted that implementing integrated operations planning and execution is a best practice that should yield significant improvements in efficiencies and costs. Over the last decade, several mining and metals companies have attempted to or are in the process of designing and implementing Integrated Operations, either through a control room or a larger operations centre, with varying degrees of success. The authors were interested to create an environment where mining industry professionals would share experiences, investigate and discuss the critical success factors in the design and implementation of an integrated operations model. Under the auspices of the Global Mining Standards and Guidelines Group, over the last six months, a working group with global reach has collaborated to develop a framework for integrated operations. This presentation outlines such framework, which will be further developed into a set of Mining Industry Guidelines for Integrated Operations.

**UCA of SME: Energy Pre-Developed Longwall Recovery Room I****9:00 AM • Tuesday, February 17 • 111**

*Chairs: R. Henn<sup>1</sup>, Brierley Associates LLC, Littleton, CO  
D. Klug<sup>2</sup>, David R Klug & Associates Inc, Murray, PA*

**9:00 AM****Introductions****9:00 AM****Boring the Grosvenor Coal Mine Drifts with a Tunnel Boring Machine**

*D. Ofiara and M. Scialpi; The Robbins Company, Solon, OH*

The Grosvenor Coal Mine in Queensland, Australia is a newly developed mine with high value metallurgical coal. Two decline tunnels are required to provide access to the coal seam for mine development. Later, when the mine is in full production, the first drift will contain the main coal haulage belt. The second drift will provide access for rubber tired vehicles to provide transport of personnel, equipment, and supplies. The drifts are mined at gradients of 1:6 and 1:8 respectively and are 870m and 1160m long. Anglo American, the mine operator, decided to use a Robbins shielded TBM to bore these two access tunnels.

**9:20 AM****Details on the Signal Peak Energy Pre-Developed Longwall Recovery Room**

*R. Ochsner; Signal Peak Energy LLC, Roundup, MT*

Longwall recovery history was made at Signal Peak Energy's, Bull Mountains Mine No. 1 in late January of 2014 by successfully mining into and recovering the longwall in a pre-developed recovery entry. This longwall recovery fulfilled the Signal Peak vision to safely advance the longwall into a pre-developed recovery room without the need to stop and install any supplemental roof support. Unlike other pre-driven recovery rooms, the 42 ft wide recovery room was driven in two 21ft wide phases. This entry was bolted, meshed, and then completely back-filled with a specially formulated, cuttable, low density concrete. The usage of cellular concrete.

**9:35 AM****Cellular Concrete Used For the Longwall Recovery Room at Bull Mountains Mine No. 1**

*R. Palladino; Aerix Industries, Golden, CO*

Longwall recovery history was made at Signal Peak Energy's, Bull Mountains Mine No. 1 in late January of 2014 by successfully mining into and recovering the longwall in a pre-developed recovery entry. This longwall recovery fulfilled the Signal Peak

vision to safely advance the longwall into a pre-developed recovery room without the need to stop and install any supplemental roof support. Unlike other pre-driven recovery rooms, the 42 ft wide recovery room was driven in two 21ft wide phases. This entry was bolted, meshed, and then completely back-filled with a specially formulated, cuttable, low density concrete. The usage of cellular concrete.

**9:50 AM**

## **Silver Lake Segmental Tunnel Lining**

*K. Braun; L-7 Services LLC, Golden, CO*

The precast concrete segmental lining for the Silver Lake Tunnel in Los Angeles incorporated some modern advances for precast lining systems including steel fiber reinforcement and radial guide rods to eliminate the need for conventional steel rebar cages and radial connection bolts. The segmental tunnel lining and the design approach will be discussed along with a couple of challenges that developed during the construction of the tunnel.

**10:10 AM**

## **Are You Drilling Blind?**

*B. Warfield; Atlas Copco, Roseville, CA*

How do you know what to expect ahead of the face? Was there enough geotechnical drilling done to make you aware of all conditions? Do you expect to encounter high pressure water, flowing ground, lenses of softer (or harder) material or did you bid this project to be in homogenous material the whole length? Measurement While Drilling (MWD) is one method of gathering data to help determine future conditions. This presentation intends to provide an update of what is involved and how the data can be used to keep you aware of changing ground conditions.

**10:30 AM**

## **Evaluation of Maximum Permissible Permeation Grouting Pressure in Soft Ground**

*L. Porras; Colorado School of Mines, Golden, CO*

A widely recognized rule of thumb in the United States dictates that maximum pressure in soils should be one half of a psi per foot of depth. Well-documented experience in the United States and other countries, however, has proven this rule of thumb to be overly conservative. It is always preferable to use the highest safe pressure, as this will expedite the work and force the grout into the smallest pores and cause it to penetrate farther, making the work more economical. It is to be expected that a higher pressure results in a larger effective radius and an optimal solution. The pressure has to be restricted to a level that is perceived to avoid undesirable hydraulic fracturing, jacking, or heave of the ground.

**10:50 AM****Geoelectrics-While-Tunneling: Influence of the TBM tunneling environment and implementation strategies through use of finite element methods***K. Schaeffer; Colorado School of Mines, Golden, CO*

TBM tunnel excavation is susceptible to uncertainties and risk, which can be hazardous and costly to the excavation process. Methods that can continuously image the geologic conditions, in real-time ahead of the TBM, can help lower the uncertainty, and therefore, lower the risk involved during excavation. Electrical geophysical methods used in earth based applications, called geoelectrics, have been well established and can image ground conditions over many applications. It is unclear as to whether or not they can be as successful in a TBM tunneling environment. This presentation will speak to some of the complexities associated with the implementation of geoelectrics-while-tunneling and discuss some possible approaches for implementation through use of finite element modeling.

**Valuation I: Lessons Learned****9:00 AM • Tuesday, February 17 • 112***Chair: C. Wyatt, Behre Dolbear, Golden, CO***9:00 AM****Introductions****9:05 AM****The Comparison Sales Approach to Valuation: Science or Black Magic?***G. Davis; Economics and Business, Colorado School of Mines, Golden, CO*

The comparison sales approach recommends that a target asset can be valued by finding sales of comparable properties and adjusting those sales for geological, geographical, political, and economic differences. The most common, and often only, adjustment is for size, where a per unit value is taken from the comparison sale and applied to the number of units of metal at the target property. This method assumes that project value is linear in scale, with an intercept of zero. The assumption has, to my knowledge, never been tested. In this paper I point out the linearity assumption made by this approach and show that it is unlikely to hold. The data I use for the analysis comes from engineering designs for an open pit copper project of the same grade and geology but of different scales. I also point out that much of the recommended practice of comparison sales has never been empirically validated, and as such this valuation method more black magic than science.

**9:21 AM****Comparable Mineral Properties – A Widening of Meaning for Appraisals***T. Ellis; Ellis International Services, Denver, CO*

In August 2013, The Appraisal Foundation's Appraisal Practices Board (APB) issued Valuation Advisory #4, "Identifying Comparable Properties." The analysis and examples in this Advisory lead to a wider meaning of the term "comparable properties" than this author expected. The Advisory is directed at the appraisal of real property of all kinds, including mineral interests, as indicated by two mineral property valuation papers being included in its Appendix of suggested further reading. The author discusses with the aid of examples, how this Advisory may influence the work of mineral property appraisers, particularly for situations where their sales comparison analysis may be challenged.

**9:37 AM****Beware the Perfect Valuation Engagement!***T. Knobloch; AIMA, Marietta, OH*

Consultants often presented with various job opportunities. Some are with existing clients, some new clients that work out well, some are new clients that we later regret, while others are turned away viewed as being not worth the trouble. Every once in a while everything seems perfect: A significant valuation, definable objectives, organized information, generous timeline, two separate valuations, a signed contract, and cash deposit. This particular valuation engagement was related to the oil & gas interests in multiple properties in three states owned by a husband (deceased) and wife. Two evaluations: one for the deceased husband and for the wife's estate planning purposes. Preliminary client information was provided, a pre-valuation meeting held with the clients after data review, and then the work began. The process included an interesting first meeting, a second overlapping appraiser, conflicting information, withheld information, a client who did not understand the valuation purpose, and report changes after finals submitted. A review will be presented reviewing the lessons learned in this "Perfect Valuation".

**9:53 AM****Alternative Mine Development and Capital Project Strategies***M. Young; SME, Denver, CO*

Completed in an environment of resources restraints, complex mining capital projects are fragile and sensitive to failure on overruns and against other metrics. New delivery methods are required to ensure project certainty: safe delivery- on time and on budget within stakeholder expectations of success. Innovative strategies from the initial feasibility design and project financing through design, construction and operations ramp-up will be identified and discussed. Risk identification, mitigation and assigned responsibility; proactive versus reactive problem solving; elimination of scope changes and endless cost reimbursable cycles can be addressed through realigned project teams, assignments and accountability. Innovative pro-

cesses with appropriate project owner engagement within the committed team also accelerates the design, planning, permitting and construction process.

**10:09 AM**

### **Marcellus Shale: Not your ordinary unconventional natural gas play**

*F. Bertrand; BertrandData Services, Towanda, PA*

The Marcellus shale play in the Eastern US provides valuation experts with challenges. This boom had a start, accelerated, peaked, and subsided. What effects has this event had on the economic, social and political climate in the Northern Tier? One senior landman described the population as, "the most trusting he has seen in 30 years of this work". Chesapeake Energy has been targeted (fairly or unfairly) as a bad player. Pennsylvania law mandates a 12.5% minimum royalty. We shall explore Chesapeake's clever ploy to maximize profits and minimize payouts., Although gas continues to flow from its' wells,,Chesapeake's lessors purportedly receive little or in some cases -0- zero royalties. The discussion will present what the current state of the mature market, how drummers (travelling lawyers, rights buyers) have descended upon the Shale play, enticing owners to sign on to lawsuits, sell their rights to speculators and complain to local state legislators. Is the fault Chesapeake's, or the local lawyers who jumped into the lease business without knowing what a standard 88 lease does present.. As the Chinese saying goes, "may you live in interesting times"

**10:25 AM**

### **Mineral valuation in business combination settings**

*G. Loke; American Appraisal Associates, Inc., Milwaukee, WI*

The discussion will present the following topics: 1. The role of the mineral appraiser in purchase price allocation setting 2. Acceptance vs testing of the data submitted for consideration of its contributory value to the enterprise 3. If values are submitted, basis of estimate (eg. cost, market, income; USGAAP Level 1, 2, 3) 4. If cost approach is the basis, proper consideration of physical depreciation, functional obsolescence, and/or economic obsolescence. 5. Proof of statement to the general agreement of market participants that are not motivated to have a robust nor conservative value. 6. Auditor's review and acceptance

**10:41 AM**

### **The Role of Mentoring in the Development of New Minerals Appraisers**

*F. Pirkle<sup>1</sup> and W. Bagby<sup>2</sup>; <sup>1</sup>Gannett Fleming, Inc, Jacksonville, FL and <sup>2</sup>WC Bagby Economic Geology, Carlsbad, CA*

A Minerals Appraiser specializes in the appraisal of properties containing minerals and thus integrates economic geology with real property appraisal. Candidates for Minerals Appraiser Certification commonly start with experience in mineral-project evaluation and a clear understanding of mineral resource cat-

egories coupled with the desire to apply this experience and knowledge to minerals appraisal. Certified Minerals Appraisers serve as mentors to support and encourage candidates in learning how to apply their mineral-project evaluation experience and mineral-deposit understanding to minerals appraisal. The appraisal concepts of market value versus project economic evaluation, highest and best use, the income, cost, and comparable sales approaches to value, and appraisal guidelines such as the Uniform Standards of Professional Appraisal Practice, Uniform Appraisal Standards for Federal Land Acquisitions, and the newer International Valuation Standards present most candidates with a steep learning curve. It is the Mentor's role to help a Mentee through this education gauntlet on his or her way to becoming a Certified Minerals Appraiser.

**10:57 AM**

### **Small-Firm Risk in New Hydrocarbon Plays**

*Z. Smith; Congdon & Company, Endicott, NY*

For the purpose of valuing land in new hydrocarbon plays, there appears to be a habit of assuming that "all companies are created equal" and that only the terms of the lease affect value. As more acreage comes into production, we observe that even within the same township production rates vary dramatically between operators. In NE Pennsylvania, Chesapeake, Cabot and Southwest are major players with high IP rates where smaller companies typically have lower production rates. A range of "small-firm risk adjustments" to discount rates is derived from comparison of IP rate variation with the Sales Comparison Approach and observations of behavior of Institutional Investors.

**11:13 AM**

### **Enforceable Codes of Professional Ethics— Why, How, and in Practice**

*D. Abbott; Behre Dolbear & Company, Denver, CO*

Those organizations seeking recognition from regulators like the Canadian Securities Administrators for NI 43-101 need to have an enforceable code of ethics providing for discipline of members who violate the code regardless of the disciplined member's residence or where the property is located. The organization should have disciplinary procedures setting out the disciplinary process, the rights of those alleged to have violated the code, appellate procedures, and potential sanctions. Once a code of ethics and related disciplinary procedures are adopted, the organization's membership should be aware of several important aspects of their implementation. Investigations take time, frequently months. Because investigations should be conducted confidentially, those who have made allegations or those who know about particular cases often become impatient because resolution doesn't occur within a short period of time.

**Tuesday, February 17****Afternoon****Bulk Material Handling:  
Trends and New Technology****2:00 PM • Tuesday, February 17 • 709***Chair: S. Shadow, Baldor/ABB Inc***2:00 PM****Introductions****2:05 PM****New Technology to Eliminate Slope  
Conveyor Transfer Points***M. Lurie; ThyssenKrupp Industrial Solutions, Greenwood  
Village, CO*

In a new technology for slope conveyors, transfer point excavations can be eliminated by replacing multiple in-line flights by a single conveyor. The Double Belt TM system arranges for twin nested belts to equally share the tension load, thereby more than doubling the maximum lift or length achievable in a single flight. This is done without intermediate drives, while preventing catastrophic consequences if a splice were to fail. All drives as well as splicing and belt installation can be located at the surface. The Double Belt can be attractive even when a transfer excavation isn't the concern, such as where using a nested pair of moderate-strength belts can avoid the costs and risks of using an ultra-high strength belt. (Pats. Pend.)

**2:35 PM****Conveying Versus Trucking Economics***R. Munson; Industrial Engineering, Montana State University,  
Fairway, KS*

The paper summarizes the economic incentive to convey from a mine site to the plant. It focuses on an economic model that can be applied to any site to model the key variables which include volume (truckloads per day), distance from the mine to the plant (cost of conveyor), operating cost profile in the area (fuel, labor, maintenance), and local tax situation which includes tax rates and company income tax rates. The tax structure also dictates the tax depreciation benefit that is available to shield income taxes. Such a model is a must to project the net cash flow that would be used to pay out the capital investment of a conveyor. We can project the net present value based on the time value of money which results in a breakeven point somewhere in the future. The model helps to answer the critical questions: 1. When will the project break even on an after tax basis, 2. What will be the rate of return on capital invested for a given fixed project life, 3. If the tax structure changes can the project still be justified, 4. What volume is necessary to justify the conveyor investment for the given cost environment.

**3:05 PM**

15-044

**Cable Bridge Conveyor: New Suspension Bridge Based Conveyor System***Y. Zhang; Conveyor Dynamics Inc., Bellingham, WA*

Above ground, elevated belt conveyors with span >200m between support points can cross valleys, rivers, forests and buildings with minimal footprint. The Cable Bridge Conveyor is a new type of suspension bridge based belt conveyor system that has long span between support points. It combines typical belt conveyor and the improved simple suspension bridge to form a conveyor bridge. The improved simple suspension bridge places a widened bridge deck directly on suspended cables, without the need for high truss towers. The benefits include reduced cost and increase aerodynamic stability compared to conventional suspension bridges. The Cable Bridge Conveyor's compatibility with current belt conveyors allows the versatility in application.

**3:35 PM****Application of Coupled CFD-DEM Analysis to the Design of Bulk Material Transfers***S. Yee, D. Besler and P. Dunwoody; CWA Engineers Inc., Vancouver, BC, Canada*

An integrated approach to the design of bulk material transfers utilizing both discrete element method (DEM) and computational fluid dynamics (CFD) yields a dynamic model of the complete system. DEM provides numerical simulation of material flow and trajectories in bins and chutes, including the influence of moving surfaces such as gates, diverters, and conveyor belts. CFD provides numerical simulation of complex fluid flow problems. By utilizing a coupled DEM and CFD simulation a picture of the combined air and material flow can be obtained. Validation using field observations to configure and adjust the dynamic model is a critical step in the modeling process. Once our virtual system has been aligned to our client's site specific conditions we can optimize the chutework design to minimize turbulent material and air flow through the transfer, thus significantly reducing material degradation and dust generation.

**Coal & Energy: Breathing Air Supplies I****2:00 PM • Tuesday, February 17 • 504***Chair: R. Fernando, OMSHR, Pittsburgh, PA***2:00 PM****Introductions**

**2:25 PM****Next Generation Breathing Air Supplies Status***R. Fernando; OMSHR, Pittsburgh, PA*

OMSHR has undertaken the task of identifying and exploring technologies towards developing the next generation of breathing air supplies for underground mining a research imperative directed by the MINER Act. This paper outlines the current status of the BAS program. The R&D effort at this time is continuing with developing different combinations and configurations of BAS such as the next generation SCSRs with Docking & Switch-Over Valves, Hood/Mask and Very High Pressure Cylinders. The 4-hour closed-circuit rescue breathing apparatus is being examined with a view to improving the performance efficiency. Cryogenics are being explored for both open and closed circuit systems with a view to having a long operational time from a smaller sized unit. Cryogenics as another gas supply for Refuge Alternatives is also under study in this program. A multifaceted contract program is currently underway to assist with achieving the next generation improved BAS.

**2:50 PM****Self-Contained Self Rescuer Breathing Apparatus Improvements***B. Toole and J. Cornman; NAVY, NAVSEA, Panama City, FL*

The Office of Mine Safety and Health Research in conjunction with the Naval Surface Warfare Center Panama City Division is identifying and adopting technologies for improvement of a self-contained self-rescuer (SCSR) breathing apparatus for underground mine emergencies. This work covers the development of closed-circuit oxygen breathing apparatus (CCBA) prototypes that incorporate technologies used in other fields such as diving. Current SCSRs used in the coal mining industry were evaluated for baseline performance. It was found that the largest areas for improvement are in heat transfer, ergonomics, and in deployment methods. The ergonomic effort addresses potential areas for improvement to minimize the overall footprint and weight load on the user while making the units comfortable to wear. The heat transfer work addresses removing unwanted heat, which has two main benefits: increasing the CO<sub>2</sub> absorbent efficiency and reducing the user's inspired gas temperature. The work on deployment methods addresses the ability to decrease the time and increase the ease at which the apparatus is deployed.

**3:15 PM****Real Time Monitor of the CO<sub>2</sub> Scrubber in a Closed Circuit Respirator (rebreather)***D. Warkander; U.S. Navy Experimental Diving Unit, Panama City, FL*

The stated endurance time of the CO<sub>2</sub> scrubber in a closed circuit respirator (CCR) is generally pessimistic. Most of the time usage is less and not all of the absorbent is used. If remaining time were known in real time, a CCR could be made lighter in weight and the cost of absorbent would be reduced. Conversely, with existing scrubber size, the endurance could be

longer. The capacity of a CO<sub>2</sub> scrubber is not fixed, but varies with the workload and ambient conditions. Even when the same person packs it with absorbent from the same container a variation of 5 to 10% can be expected. A real time scrubber monitor would give the wearer information on how much capacity is left, similarly to what a pressure gauge reveals about remaining gas. We have developed such a scrubber gauge (U.S. patent 6,618,687 and others) that relies on temperature measurements in the absorbent (which releases heat). These changes are consistent and repeatable. Readings are independent of ambient conditions and previous use. The gauge has been shown to work both under CCR use and in diving rebreathers (military and civilian). A scrubber gauge can be built at low cost and can easily be retrofitted in existing CCRs.

**3:40 PM**

### **Meeting Regulatory Escape Requirements with Compressed Breathing Air**

*K. Armstrong; Draeger Safety, Inc., Pittsburgh, PA*

The Mine Improvement and New Emergency Response (MINER) Act of 2006 required operators of underground coal mines to improve accident preparedness. As a result of the MINER Act and the Emergency Mine Evacuation Final Rule (Dec 2006) there was an increase in the number of self-contained self-rescue devices (SCSRs) within the industry. At the same time, the legislation called for improved escape solutions that reduced the hazards of exposure, enabled communication and instituted the use of a written emergency response plan (ERP). As the mining industry has done its part to fulfill the requirements of the MINER Act, safety manufacturers have also been working to develop innovative technologies to meet industry needs. Today, the introduction of the new 2015 Closed Circuit Escape Respirator (CCER) standard presents an opportunity for mine safety to take another step forward. This presentation outlines how the use of a Self-Contained Breathing Apparatus (SCBA) with an underground refill system can increase mine safety, mitigate the risk of downtime as a result of mine fires, and fulfill current compliance requirements.

**4:05 PM**

### **SCBA Filling from Auto-Cascading Air Refill Stations**

*R. Fernando; OMSHR, Pittsburgh, PA*

Air Refill Stations are used in conjunction with Self-contained Breathing Apparatus (open-circuit) (SCBA) for mine escape from the outby areas in an underground mine after a mine emergency. This escape method was pioneered in Australian mines and introduced to USA in 2007. The Refill Stations are designed with separate air banks controlled by auto-cascading pneumatics to maximize the use of the stored high pressure (6,000psi) breathing air when filling the SCBAs. This paper will present results of SCBA fill tests conducted from different refill stations. This data is used for determining the maximum number of SCBA fills for a particular design of Refill Station and help with deploying this system underground as part of a mine escape plan. Further, through analysis information will be gained for optimizing their design.

**Coal & Energy: Developments in Health and Safety****2:00 PM • Tuesday, February 17 • 501***Chair: S. Bealko, GMS Mine Repair, Oakland, MD***2:00 PM****Introductions****2:05 PM****Risk Reduction by Applying CORESafety***J. Pugh; Alpha Natural Resources, Charleston, WV*

Mining involves many potential hazards and risk. This presentation will review how Alpha Natural Resources is utilizing the CORESafety framework of risk management and Bow Tie Analysis as a means to assess and quantify current safeguards in place, identify areas of weakness, and then to develop key process controls that require standard protocols. Through this work a better understanding of the risk and improved outcomes can be achieved.

**2:25 PM****Risk Management or Mismanagement?***D. Beerbower<sup>1</sup> and J. Knowles<sup>2</sup>; <sup>1</sup>Beerbower Safety Associates LLC, Wildwood, MO and <sup>2</sup>KB Risk Services LLC, Kurri Kurri, NSW, Australia*

Can the U.S. mining industry achieve its long-stated goal of Zero fatalities? This is the question that has plagued the industry in a time when the injury incidence rate continues to drop, but the number of fatalities seems to have plateaued. Major gains in the last few years mean that preventing accidents and injuries today is getting harder. The industry must advance from the old command and control management style to a risk management based system. The recent initiative from the National Mining Association (NMA), with the introduction of the risk based COREsafety process, is an excellent framework for companies who want to go to the next level. Implementing a risk management program into the mining environment is something that has been done successfully in the Australian mining industry over the past twenty years with excellent results. Mining companies there have worked for many years without a single fatality and in some cases no lost time injuries (LTI's). This paper will explore the process of implementing a practical risk management program into the mining industry.

**2:45 PM**

15-012

## **A Preliminary Evaluation of a Through-the-Earth (TTE) Communications System at an Underground Coal Mine in Eastern Kentucky**

*E. Jong<sup>1</sup>, S. Schafrik<sup>1</sup>, E. Gilliland<sup>1</sup> and C. Weiss<sup>2</sup>; <sup>1</sup>Virginia Center for Coal and Energy Research, Virginia Tech, Blacksburg, VA and <sup>2</sup>Geophysics and Atmospheric Sciences Department, Sandia National Laboratories, Albuquerque, NM*

A commercially available Through-the-Earth (TTE) communications system was evaluated at an underground coal mine in eastern Kentucky. This field study was conducted as part of a larger multi-site evaluation of available TTE systems to determine their operational sensitivity. Field testing is being performed along with simulation techniques developed for geophysical surveys. The results of the field test will additionally be used to determine the applicability of these simulation techniques to TTE communications. The mine detailed in this paper was idled at the time of the study, which provided the nearest practical representation of a post-event mine shutdown. For this study, the three following communication modes were tested: surface-to-underground, underground-to-surface and surface-to-surface. Standard deployments of the TTE system using the manufacturer's recommended procedures were able to achieve clear communications between underground and surface locations. Other arrangements of the units yielded intriguing results, some of which were predicted by computer simulations, others were unexpected. Future experimentation is planned to further evaluate the observed phenomena.

**3:05 PM**

15-081

## **Underground Field Tests of Second-Generation Proximity Detection Systems on Continuous Mining Machines**

*J. Carr, C. Jobes, T. Lutz and J. Yonkey; Office of Mine Safety and Health Research (OMSHR), National Institute for Occupational Safety and Health (NIOSH), Pittsburgh, PA*

Since 1984, 38 miners in the United States have been killed when they were struck by a continuous mining machine. Proximity detection provides a means to prevent accidents like these. Researchers at the National Institute for Occupational Safety and Health (NIOSH) conducted a series of underground tests to evaluate the accuracy and repeatability of proximity detection systems under a number of conditions such as varying the orientation and height of the personal wearable device (PWD), moving the PWD close to the trailing cable, and activating mining mode. At a previous SME Annual Meeting, results from tests on first-generation proximity detection systems were presented. This paper will provide results from the same tests performed with second-generation systems. The results show that performance has improved. For example, the negative impact of PWD orientation and the trailing cable has been reduced. However, some inconsistencies remain. Notably, performance changes dramatically when mining mode is activated. Proximity detection is a valuable tool for preventing fatalities, and the use of these systems is expected to significantly improve safety.

**Coal & Energy: Dust Control I****2:00 PM • Tuesday, February 17 • 502**

Chairs: **J. Colinet**<sup>1</sup>, NIOSH, Pittsburgh, PA  
**J. Rider**<sup>2</sup>, CDC-NIOSH/Mining Safety and Health,  
Pittsburgh, PA

**2:00 PM****Introductions****2:05 PM****Analysis and Evaluation of the Application of a Flooded-Bed Dust Scrubber to a Longwall Shearer Operating in a US Coal Seam Using Computational Fluid Dynamics**

*A. Kumar, W. Wedding and T. Novak; Department of Mining Engineering, University of Kentucky, Lexington, KY*

Dust is a detrimental, but unavoidable consequence of any mining process. It is particularly problematic in underground coal mining, where respirable coal dust poses a potential health risk of coal workers' pneumoconiosis (CWP). Float dust if not adequately diluted with rock dust, also creates the potential for a dust explosion initiated by a methane ignition. Furthermore, recently promulgated dust regulations for lowering a miner's exposure to respirable coal dust will soon call for dramatic improvements in dust suppression and capture. This is especially true with longwall mining systems where production rates have increased significantly in the last ten years with an attendant rise in dust production. Computational fluid dynamics (CFD) results are presented for a research project with the primary goal of applying a flooded-bed dust scrubber, with high capture and cleaning efficiencies, to a Joy 7LS longwall shearer operating in a 7-ft (2.1 m) coal seam. CFD software is used to analyze and evaluate airflow patterns and dust concentrations, under various arrangements and conditions, around the active mining zone of the shearer for maximizing the capture efficiency of the scrubber.

**2:25 PM**

15-077

**Laboratory Assessment of a Tailgate Spray Manifold to Reduce Dust Exposures for Shearer Face Personnel**

*J. Rider and G. Joy; NIOSH, Pittsburgh, PA*

Technical advances in longwall mining over the last several years has resulted in much larger and faster shearers that have the capability of mining at speeds over 100 ft/min. This has resulted in a substantial increase in the amount of dust that is generated at the shearer and during shield advances. NIOSH's Pittsburgh Research Laboratory is investigating a manifold mounted on the tailgate end of the shearer that has a series of sprays oriented parallel to the tailgate ranging arm. These sprays act as a water

curtain confining the dust plume near face preventing the dust from drifting into the walkway thus creating a clean air envelope for inby longwall personnel. Three different tailgate spray manifolds systems were tested and evaluated at the NIOSH's Pittsburgh Longwall Test Facility. Manifolds were equipped with hollow cone and flat fan sprays and evaluated at three velocities, 500, 700, and 900 fpm at sprays pressures of 100, 150, and 200 psi. Reductions in dust concentrations were observed at six face sampling locations for all the tailgate manifold systems at each of the tested spray pressures and face velocities.

**2:45 PM**

15-004

### **Influence of Continuous Mining Arrangements on Respirable Dust Exposures**

*T. Beck<sup>1</sup>, J. Organiscak<sup>1</sup>, D. Pollock<sup>2</sup>, J. Potts<sup>1</sup> and W. Reed<sup>1</sup>; <sup>1</sup>NIOSH - Office of Mine Safety and Health Research, Pittsburgh, PA and <sup>2</sup>U.S. Department of Veteran Affairs, Erie, PA*

Changes in mining arrangements, such as, face ventilation configuration, orientation of crosscuts mined in relation to the section ventilation, and equipment operator positioning, can impact the ability of dust controls to reduce occupational respirable dust exposures. This study reports and analyzes dust concentrations measured by NIOSH-OMSHR for both remote-controlled continuous mining machine operators and haulage operators at ten U.S. underground mines. Results of these respirable dust surveys show that continuous miner exposures varied little based on depth of cut, but are significantly affected by ventilation configuration. Haulage operators experienced elevated concentrations in blowing face ventilation. The type of cut influenced exposures, with elevated exposures for both continuous miner operators and haulage operators when completing crosscuts into, or against, the section airflow. Individual cuts are highlighted to demonstrate instances of minimal and excessive dust exposure attributable to particular mining configurations. These findings form the basis of recommendations for lowering face worker dust exposures when performing a variety of continuous mining cuts.

**3:05 PM**

### **Effect of Ventilation on the Effectivity of dust control in a hardcoal longwall face**

*E. Clausen and O. Langefeld; Institute of Mining, Clausthal University of Technology, Clausthal-Zellerfeld, Germany*

For providing safe working conditions in a hardcoal longwall face several dust suppression measures exist. This paper investigates the effect of ventilation on the effectivity of dust suppression concerning the available amount of water for wetting the coal face. Therefore different flat and cone nozzles were tested and analysed in a wind tunnel, installed at the Institute of Mining at Clausthal University of Technology, varying the water pressure, air velocity, distance between the nozzle and face as well as the direction of installation of the flat nozzles. The results could then be used for the selection of suitable nozzles subject to different longwall conditions and the specification of adjustable parameters.

**3:25 PM**

15-137

**Preliminary Development of a TGA Method for Determining Coal to Mineral Ratios in Respirable Dust Samples**

*C. Keles, M. Scaggs and E. Sarver; Mining and Minerals Engineering, Virginia Polytechnic Institute and State University, Blacksburg, VA*

Respirable dust in underground coal mines has long been associated with lung diseases, and regular dust sampling is required for assessing occupational exposures. At present, respirable dust concentration and crystalline silica content are commonly determined, but considering recent and yet unexplained increases in the incidence of lung disease amongst miners in specific geographic regions, more information about specific dust characteristics is urgently needed. While particle-level dust analysis is ideal, it is impractical for large numbers of dust samples because it is both time and cost intensive. Thermogravimetric analysis (TGA), however, is an alternative option, which offers the ability to determine the total coal to mineral mass ratio in a dust sample – analogous to proximate analysis of bulk coal samples for determining ash content. Here, preliminary development of a TGA method for this purpose is presented. The method is being developed to evaluate dust collected on mixed cellulose ester (MCE) filters using approved permissible sampling equipment.

**3:45 PM****“Dustless” Soft Handling Transfers**

*S. Yee and D. Besler; CWA Engineers Inc., Vancouver, BC, Canada*

In recent years dust management has become a growing consideration for health, safety and environmental management. Whether to meet Fire Code, regulatory codes and standards, or corporate goals to reduce or eliminate hazards associated with dust generation and emission, facility operators are increasingly seeking dust management solutions. Utilizing state-of-the-art techniques combining discrete element method (DEM) and computational fluid dynamics (CFD), CWA has developed an effective modeling tool to accurately predict material flow and trajectories in bins and chutes. As a result, we can optimize our chutework designs to materials at the transfer points, thus significantly reducing dust generation and material degradation. The recent expansion of the coal handling system at Neptune Bulk Terminals in North Vancouver, British Columbia, presented an opportunity to apply these techniques for the design of “dustless” soft handling conveyor transfers in an environmentally sensitive area.

**Coal & Energy: Mine Planning****2:00 PM • Tuesday, February 17 • 505**

*Chairs: N. LaBranche<sup>1</sup>, Deswik, Brisbane, QLD  
P. Doig<sup>2</sup>, Deswik Mining, Spring Hill, QLD*

**2:00 PM****Introductions****2:05 PM**

15-061

**The Measurement and Control of Dilution in an Underground Coal Operation**

*M. Noppe; Xstract Mining Consultants, Brisbane, QLD, Australia*

Dilution in underground coal operations can be underestimated during feasibility studies, with disastrous economic consequences. Every one per cent of stone waste can reduce run-of-mine coal quality proportionally, including increasing the abrasiveness of the run-of-mine coal. Where little or no beneficiation takes place, penalties imposed for not meeting contractual specifications can amount to some million dollars per year. Additional underground information is essential for understanding and controlling dilution to acceptable levels. Much of this short-term data can be collected through underground channel sampling and horizon control measurements taken during mine development and longwall extraction. The information can be used in a robust grade control process to predict run-of-mine coal qualities, reduce dilution and improve mining horizon control on a short-term basis with resulting improvements in coal quality and productivity. A case study where this has been successful is presented.

**2:25 PM****Helping Search for a Better Way**

*J. Wientjes; Application Engineering, Komatsu America Corp., Peoria, IL*

The Application Engineering department within Komatsu America Corp. was recently asked by a customer to evaluate a complex multi-seam deposit facing increasing strip ratio conditions with an aging equipment fleet. Given the uncertainty regarding production volume requirements and definitive deposition knowledge, this study had to deviate from producing a typical finite result, but instead create a series of tools that allowed the evaluation of variable geologic conditions and production goals. To perform such an exercise, Komatsu used its unique mining analysis software to identify the proper equipment fleet and then project the performance of this equipment for a multitude of strata horizons, thicknesses and column elevations. This presentation will describe the processes utilized to perform this exercise. Time will be taken to illustrate the design principles of the proprietary software and its capabilities that served as a foundation for this study. Then, the distinctive eval-

uation tools will be reviewed in detail to convey how variables in production goals and deposition conditions can be represented in a simplified and understandable manner.

**2:45 PM**

### **Value Impacts of Truck Limited Scheduling**

*P. Doig; Deswik Mining, Spring Hill, QLD, Australia*

Recent developments in software have allowed the dynamic integration of haulage analysis with mining schedules. Engineers can now create mining schedules in conjunction with dumping schedules, allowing mining schedules to reflect the restrictions created by the number of available trucks, combined with dynamic consideration of available in-pit and out-of-pit dumping locations. A study was completed producing a mining schedule in conjunction with a dumping schedule and haulage analysis. Multiple schedules were run with various haulage strategies and truck availability to identify the impacts production, and revenue. A financial analysis was then completed where a Net Present Value was calculated for each scenario. The study showed that trucking shortfalls can significantly impact schedules and cost estimations, both in terms of cost as well as revenue lost when trucks cannot maintain forecast production rates, thus dumping schedules and haulage analysis should be completed simultaneously.

**3:05 PM**

### **Open Pit Mine Production Scheduling with Stock Piling**

*M. Rezakhah and A. Newman; Economics, Colorado School of Mines, Golden, CO*

We present several ways of considering stockpiling in open pit mine production scheduling, including (i) individual stockpiles for each block, (ii) homogeneously mixed stockpile, and (iii) binned stockpiles with pessimistic grade estimates. We also present a new model to find a better lower bound for the problem. These models are formulated for a currently operational mine and compared to results without stockpiling in order to assess the benefits of stockpiling and to analyze the relationship between milling capacity and stockpiling value.

**3:25 PM**

15-144

### **Non-conventional surface ground behaviour induced by underground mining in Pennsylvania**

*B. Hebblewhite<sup>1</sup> and R. Gray<sup>2</sup>; <sup>1</sup>University of New South Wales Australia, Sydney, NSW, Australia and <sup>2</sup>2. DiGioia Gray & Associates, Pittsburgh, PA*

Experience from Australia has identified what is known as non-conventional surface subsidence behaviour. This occurs under irregular surface topography, resulting in valley closure, valley floor uplift or “upsidence”, and far-field horizontal movements – even occurring beyond conventional “angle of draw”

limits. This paper discusses such behaviour recently observed in Pennsylvania and focuses on the 2005 case of Duke Lake Dam in Ryerson Station State Park. In July 2005, there was a significant increase in water leakage through a number of growing cracks in the dam leading to the dam being breached to avoid an uncontrolled failure. An underground longwall mine was located approximately 900ft to the north, mining at depths of 330 – 720ft. Investigations (including a subsequent ground movement monitoring program) found a range of evidence in the vicinity suggesting that valley closure and far-field horizontal movements may have occurred resulting from the adjacent mining. The paper discusses non-conventional subsidence behaviour and the Ryerson State Park case study, including an assessment of mining, geology and subsidence impacts and suggested ground behavioural mechanisms.

**3:45 PM**

15-141

### **Impact of Past Issues on Mine-Size Planning in the Coal Industry: Mine-Size Transitions from 2002-2012**

*S. Eslambolchi and R. Grayson; Energy and Mineral Engineering, The Pennsylvania State University, University Park, PA*

In making strategic economic decisions, it is important for a mining company to gain insights on the impact of significant political, social and economic issues when planning for present and future mines. The size of any mine, measured by the average number of employees working in the mine, will likely vary according to the pressures generated by the significant issues from one year to another. The objective of this study is to develop a model that represents U.S. underground coal mine size transitions during the period 2002-2012 using data derived from the MSHA databases. Coupled with information on significant issues over the past ten years, this model is used to gain insight on the impact of the issues on mine sizes. Results indicate that the structural impact of the combined driving pressures can be discerned by examining the year-to-year stability of mine-size categories. The effects of The MINER Act, the Obama Administration environmental policies on coal, and the coal market are evident. The lessons learned from these analyses give good insights on what the industry and market responses have been on the structure of the underground coal industry over the period of study.

### **Coal & Energy: Surface Mining Processes and Emerging Issues in Reclamation**

**2:00 PM • Tuesday, February 17 • 503**

*Chairs: P. Conrad<sup>1</sup>, Montana Tech, Butte, MT  
P. Tukkaraja<sup>2</sup>, South Dakota School of Mines and Technology, Rapid City, SD*

*Sponsored by: Civil and Environmental Consultants*

**2:00 PM****Introductions****2:05 PM****Successful Restoration of the Belle Fourche River and It's Hydrologic Functions at a Major Powder River Basin Coal Mine***D. Maunder; Technical Services, Cloud Peak Energy, Gillette, WY*

Reconstruction of the hydrologic functions is an essential component of a successful reclamation program and development of a landscape which will effectively support the post-mining land use. A thorough understanding of the baseline hydrology is necessary to develop and implement plans for construction of features which will restore these functions. This paper presents a case study of the regulatory requirements and successful reconstruction of an intermittent stream on reclaimed mine lands.

**2:25 PM****Stream Restoration Initiative at the Jewett Lignite Mine***D. Ezell and J. Young; Engineering and Environmental, Texas Westmoreland Coal Company, Jewett, TX*

In 2009 Texas Westmoreland Coal Company embarked on a mission to not only improve the stream restoration efforts at the Jewett Mine, but to build a process that would be recognized as the premier stream restoration program in the US. This effort stemmed from the awareness being placed on the growing emphasis across the country relating to overall stream function, stream protection and obstacles faced with wetland mitigation. Our process begins with gathering of baseline data of the impacted stream channel and the design component feeds from this data and ensures that a natural channel is developed for construction. The construction process utilizes GPS through which digital terrain models are designed to guide the operator in building the envisioned plan. Additionally, through the use of these innovative technologies, our restored streams exhibit increased geo-fluvial characteristics and require far less reinforced structures. The Jewett Mine has paved a new path forward with respect to stream restoration by studying the stream channel prior to disturbance, developing a plan that honors the original system and transitioning that plan into an effective means of construction

**2:45 PM****Historic Black Diamond Coal Mine Fire Abatement***D. Hallman; Applied GeoLogic, Evergreen, CO*

Located approximately 1 mile northwest of Meeker Colorado through dense juniper, sage, and pinon pine, the historic Black Diamond mine fire represents a high fire hazard to the town. Although the fire was documented as the cause of mine closure in 1930 and has been burning for a considerable period of time, recently increased fire activity has prompted an attempt to sup-

press and ultimately extinguish the fire. The fire is located in steep rugged terrain in an area proposed for Roadless designation. This greatly complicated the potential means and methods for mitigating the fire activity within the available construction budget. Although the fire is indicated to be confined to the shallow portions of the outcrop and mine workings, the ability to construct a soil cap or simply excavate and quench the fire was not possible due to the access limitations. A novel concept of using shotcrete to create a cap over the fire to seal air intake and exhaust zones was developed, limiting access to oxygen and choking the fire on its own CO and CO<sub>2</sub>. To withstand measured temperatures as high as 600 F at exhaust vents, a refractory shotcrete mix composed of calcium aluminate cement was specified.

**3:05 PM**

### **Overview of Optimizing Computer Simulated Haulage Studies for Conceptual Mine Planning Analysis**

*E. Achelpohl and A. Anani; Mining Engineering, Missouri S&T, Rolla, MO*

As the complexity of proposed deposits being mined has increased, so have the mine models need to understand them. One area requiring these more complex simulations is material haulage. The need to accurately simulate the haulage requirements of ore and waste is a primary concern for truck and shovel operations. In very complex deposits, comprising operating multiple ore and waste fleets is very complex simulation. The efficiency of these fleets has the potential to change with every haul route. Simulation these efficiencies are hard to determine with the current fleet simulation programs. The need exists to look at multiple fleets interactions within one pit on various haul routes is required on a high level. The goal is to determine and optimize the haulage fleet efficiency losses, number of haulage units, haulage routes, and number for fleet in operation, by using discrete event simulation with ARENA and TALPAC software packages on a coal project data set.

**3:25 PM****15-122**

### **The Anadarko Conventional Mining Oil Shale Project: Cost - Environmental - Economically Sound**

*A. Schissler<sup>1</sup> and H. Nage<sup>2</sup>; <sup>1</sup>Mining Engineering, Colorado School of Mines, Littleton, CO and <sup>2</sup>Minerals Department, Anadarko, The Woodlands, TX*

Anadarko Petroleum Corporation owns extensive oil shale properties in southern Wyoming acquired as part of the original Union Pacific Land Grant of the 1860s. These holdings occur throughout the Green River Formation. Kinney Rim in the Washakie Basin was selected for further study due to proximity to infrastructure, ore grade, and low mining cost. The area is a low-overburden resource that can be developed using surface mining and conventional retorting. The purpose of this scoping study is to present the results of environmental analysis and timeline, the mine plan, and surface ore processing for a 10,000 barrel per day operation.

**Environmental: Materials Characterization:  
Advancing the State of the Art****2:00 PM • Tuesday, February 17 • 105**

Chairs: **B. Hanna**<sup>1</sup>, *Itasca Denver, Inc., Lakewood, CO*  
**B. Greer**<sup>2</sup>, *Integral Consulting Inc., Louisville, CO*

**2:00 PM****Introductions****2:05 PM****A Laboratory's Response to Rule and Regulation Changes**

*N. Ross; WETLAB, Sparks, NV*

Due to the ever evolving and dynamic nature of the mining industry, it has never been more critical to stay current with the regulatory and legislative landscape. An important component of this exercise is communication with other shareholders, specifically the analytical laboratories that perform compliance testing for the mining operations. With new mandates regarding such issues as mercury and cyanide testing, it is vital to have open and on-going dialogue with laboratory partners to help understand and react to new decisions being made. Part of this panel's discussion will revolve around how the laboratory responds to rule and regulation changes, and in turn partners with the mining operations to help ensure continued permit compliance.

**2:25 PM****Calibrating the Humidity Cell Test Procedure**

*M. Williamson; Geochemical Solutions, Loveland, CO*

As part of environmental permitting programs, the mineral industry has come to rely on empirical measurements of pyrite (and other sulfide mineral) reaction rates using the Humidity Cell Test (HCT). The HCT is widely used but limited effort has been made to assess geochemical processes relative to existing geochemical literature. A series of well-constrained HCT experiments have been conducted using simple mineral assemblages, with known mineral grain sizes. Tests have been conducted using pyrite + quartz and pyrite + quartz + calcite. Testing has been conducted using two separate pyrite grain sizes. The proportion of liquid to vapor water in the system has also been investigated by altering the established procedure to increase the vapor relative to liquid phase (vapor-enhanced). Results describe the rate of pyrite oxidation relative to grain size, the presence/absence of calcite and biweekly versus weekly flushing of test cells. Data from tests conducted using two different pyrite grain sizes (reactive surface area) indicate the rate of pyrite oxidation in liquid+vapor phase conditions does not scale linearly with reactive surface area.

**2:45 PM****Mineral Specific Responses in Peroxide Oxidation Tests***A. Nicholson, B. Greer and S. Helgen; Integral Consulting, Louisville, CO*

Peroxide oxidation of rock samples in Net Acid Generation (NAG) tests is a common and cost effective technique to assess the potential of mine materials to generate acid in the environment. While the test is useful and predictive in many circumstances, in situations with highly acid buffering minerals, a side reaction of hydroxide generation may be triggered causing the pH to increase, contrasting with the acid producing effects of sulfide oxidation. Integral Consulting, Inc. has conducted mineral specific NAG tests including various combinations of pyrite, calcite, and on common gangue minerals with high abrasion pH to assess the potential for this side reaction to occur during NAG testing. Increased understanding of mineral specific hydrogen peroxide reaction pathways will increase the utility, applicability, and regulatory acceptance of NAG testing.

**3:05 PM****Alien Extractions – Exposing the Truth behind Selective Sequential Extraction used to Understand Metal Partitioning to Environmental Media***M. Perkins<sup>1</sup>, H. Manolopoulos<sup>2</sup>, M. Hay<sup>3</sup>, J. Gillow<sup>4</sup> and P. Moran<sup>5</sup>; <sup>1</sup>ARCADIS U.S. Inc, Seattle, WA; <sup>2</sup>SENES, Toronto, ON, Canada; <sup>3</sup>ARCADIS U.S. Inc, Boulder, CO; <sup>4</sup>ARCADIS U.S. Inc, Highlands Ranch, CO and <sup>5</sup>ARCADIS U.S. Inc, Highlands Ranch, CO*

Selective Sequential Extraction (SSE) encompasses a set of batch-extraction/dissolution methods used to understand metal partitioning between the aqueous and solid phases. These methods identify the associations of specific metals with mineral phases through extraction steps thereby revealing the primary metal mobilization and attenuation mechanisms. For example, certain SSE methods can differentiate between metals that are adsorbed to or coprecipitated with oxyhydroxide minerals, associated with sulfide minerals, or incorporated into crystalline oxides and silicates. SSE methods are typically used to support site assessments when geochemical approaches or natural attenuation are being considered as a reclamation strategy. More recently, SSE has been incorporated into mine material characterization programs and used to refine predictive fate and transport models conducted in support of impact assessments. Here, we detail the application of SSE to environmental systems and address some of the challenges that currently limit broader regulatory acceptance. In addition, we examine ways to improve reproducibility by incorporating standardized quality assurance and quality control.

**3:25 PM**

15-100

**The Role of Waste Rock Characterization in Mine Development and Permitting: An Operator's Perspective***R. Clarke; Newmont Mining Corporation, Winnemucca, NV*

The long history of mine development placed virtually all focus on the economic extraction and beneficiation of ore materials, while waste rock characterization and management received less attention and consideration. Inadequate waste rock characterization has contributed to planning and management practices that are having unintended and unforeseen impacts to surface and groundwater, and in some cases lead to significant long term closure liability. New development projects carry the burden of the history of inadequate waste rock characterization and deficient impact assessment. A robust waste rock characterization program is now a prerequisite to developing operating and closure plans acceptable to regulators and the public. Waste rock characterization is analogous to ore characterization, requiring a similar investment of time and attention to detail in order to pass public and regulatory scrutiny, as well as provide a basis for defensible operating and closure plans.

**Environmental: Responsible Mining  
Environmental and Social Risks II****2:00 PM • Tuesday, February 17 • 107***Chairs: M. Jarvie Eggart<sup>1</sup>, Barr, Marquette, MI  
C. Kearney<sup>2</sup>, Barr Engineering, Hibbing, MN***2:00 PM****Introductions****2:05 PM****Reducing Closure Costs and Risks: A Cost-Benefit Analysis of Mining and Rehabilitation Methods***A. Churr; ERM, London, United Kingdom*

Achieving mine closure and relinquishment is an ongoing challenge. ERM reviewed 57 mines that ceased production between 1945 and 2012. Only five have been relinquished with no further company obligations. The difficulty in achieving closure is often tied to an inability to meet environmental and social commitments made through the life of the mine and changing stakeholder expectations as closure approaches. As such, closure provisions often fall short of the true costs of closure. ERM will present a case study which shows that by changing mining methods, the mine NPV could increase by 20 to 45% by changing the stripping and backfill methods during mining. Also:

- Mines are often overly optimistic about their ability to achieve closure, and the risks are not well understood;
- Continuous engagement with stakeholders over the life of mine is essential

in order to identify expectations and interests; - Rehabilitation must be integrated into the mine plan, rather than a standalone closure plan; and - Mining performance metrics and incentives should be weighted towards mine plan quality and adherence to mine plan rather than just production to balance short term and long term requirements.

**2:25 PM**

## **Sustainable Mine Planning : Development Planning Approaches to Create a Positive Legacy**

*A. Trippel and E. Carlson; ERM, St. Paul, MN*

Responsible mining must start with solid exploration, an ore reserve, engineering, and economic analyses—without those basics, no mine would be built. However, ERM’s global mining experience and research shows that large capital projects are slowed or stalled most often by undermanaged environmental and social issues. Leveraging lessons learned to face and resolve such issues early in mine planning is the best assurance that a project will be approved, operate smoothly, and close with a positive legacy. Sustainable development planning concepts are key risk management tools for assessing all major economic, environmental, and social issues. Increased early effort is crucial to accurately identify and manage cost and schedule ramifications of these issues. Sustainable planning methods significantly decrease subsequent mine plan revisions and consequently the need to win future stakeholder approval to construct, operate, and close. Ultimately, sustainable mining practices leave a positive legacy contributing to a successful mining industry. Highlighting successful projects in Nevada and Minnesota, we will demonstrate how employing SMP has resulted in a more efficient process.

**2:45 PM**

## **The Milos Declaration: 12 Years On**

*D. Shields<sup>1</sup>, Z. Agioutantis<sup>2</sup> and M. Karmis<sup>3</sup>; <sup>1</sup>Economics, Colorado State University, Fort Collins, CO; <sup>2</sup>Mining Engineering, University of Kentucky, Lexington, KY and <sup>3</sup>Mining and Minerals Engineering, Virginia Tech, Blacksburg, VA*

In 2003, representatives of academia, governments, intergovernmental organizations, industry, NGOs, and civil society met on the island of Milos, Greece, for the 1st Conference on Sustainable Development in the Minerals Industry (SDIMI). The purpose was to provide a forum in which participants could discuss the application of sustainable development principles in the minerals industry. The Milos Declaration was introduced at the conference. This document laid out the contributions of the minerals professional community to sustainable development, stating that the engineers, scientists, technical experts, and academics who work in, consult for, educate, study, or are in some other manner associated with the minerals industry, share a mutual responsibility with all individuals to ensure that our actions meet the needs of today without compromising the ability of future generations to satisfy their own needs. Now, 12 years on, we review the main themes and overarching conclusions reached at the 2013 SDIMI meeting, identifying trends and

areas of progress (or lack thereof). We then introduce the Milos +10 Declaration, which is an extension to the original Milos Declaration.

**3:05 PM**

### **Optimal Mine Site Energy Supply**

*A. Romero<sup>1</sup>, D. Millar<sup>1</sup>, M. Levesque<sup>1</sup> and M. Carvalho<sup>2</sup>; <sup>1</sup>Energy, Renewables & Carbon Management, MIRARCO Mining Innovation, Sudbury, ON, Canada and <sup>2</sup>Centro de Energias Alternativas e Renováveis, UFPB Universidade Federal da Paraíba, João Pessoa, Brazil*

Energy costs are increasing worldwide in the mining industry. For the Canadian metal mines, on average, energy costs are now 16% of the total production costs, and rising; for off-grid mines this fraction is higher. There has never before been greater need for robust treatment of energy in mining. This paper reviews the Optimal Mine Site Energy Supply (OMSSES) methodology for the problem of minimizing the total annual energy costs of a mine, given mine demand for energy (electricity, diesel, heating and cooling). The method allows for the optimal integration of local energy resources, utilizing renewable technologies alongside fuel and electricity networks. Two case study examples are reported. First, the influence of the distance from the electrical grid connection point on the optimal energy system design is explored for a remote mine. Building a transmission line to lower the cost of the electricity increases the total annuitized energy costs when the distance exceeds a threshold. Secondly, a process of energy demand consolidation including several mines or communities is investigated. Not surprisingly, as greater demand is consolidated, the total discounted annual cost reduces.

**3:25 PM**

### **Sustainability and Corporate Social Responsibility in the Mining Sector**

*A. Lundin<sup>1</sup> and J. Renne-Malone<sup>2</sup>; <sup>1</sup>Environmental, Operations and Construction, HDR, Englewood, CO and <sup>2</sup>Engineering, HDR, Denver, CO*

A growing number of mining companies are putting an increased emphasis on sustainability and corporate responsibility, including establishing key performance indicators, setting sustainability goals and targets, tracking progress towards meeting goals, and reporting annual progress on sustainability and corporate responsibility issues. The drivers behind the increased efforts to track, reduce and report on specific targets come in part from emerging rules and regulations that require companies to quantify and report greenhouse gas (GHG) emissions, as well as increased competitiveness, transparency, and economic benefits associated with improved operational efficiencies. This paper examines the various drivers that lead to an increased emphasis on sustainability and corporate responsibility, as well as best practices in developing a GHG emission reduction and sustainability strategy.

**3:45 PM****Implementation of Sustainability Initiatives and the Envision Rating System**

*A. Lundin<sup>1</sup> and J. Renne-Malone<sup>2</sup>; <sup>1</sup>Environmental, Operations and Construction, HDR, Englewood, CO and <sup>2</sup>Engineering, HDR, Denver, CO*

The Envision™ rating system provides a means to establish goals and document successes in creating sustainable infrastructure projects, much as the well-known LEED® rating system does for buildings. The focus of this paper is to describe the implementation of the rating system framework on projects, highlight the results, and identify the lessons learned from this approach. It will include an introduction to the purpose, process, metrics, and possibilities of using Envision to guide mining infrastructure planning, design, and construction toward environmentally and socially sustainable results. It will also include a summary of the benefits of using a sustainability rating system to guide project design, team collaboration and stakeholder input. Case studies will be presented, including an example mining project that has been run through the Envision points analysis to demonstrate how Envision works, and the benefits and applicability of the system to mining operations and reputations.

**4:05 PM****Social Management Systems - The Missing Link**

*T. Barron<sup>1</sup>, N. Schnee<sup>1</sup> and P. Martell<sup>2</sup>; <sup>1</sup>ERM, Seattle, WA and <sup>2</sup>Teck Highland Valley Partnership, Logan Lake, BC, Canada*

Extractive projects have experienced benefits from standardized approaches to managing Health and Safety and Environmental issues. Benefits include improved safety records; improved compliance with environmental permits and regulations; and more efficient use of natural resources – all translating to mitigation of risks and reduced costs to operations. To date, project-level social programs lack systematization and standardization, and their success often hinges on the capabilities of individual team members. Thus, a management systems approach applied to project-level social programs would go a long way to increasing the effectiveness of social performance of mining projects and to managing overall risk and costs to operations. This presentation will provide an overview of the vision and business case for the development of Highland Valley Copper's Social Management System (SMS). It will outline the structure and design features of the SMS, followed by observations on the challenges and examples of value generated in the process. Recommendations for other mining operations interested in embarking on a more systematized approach to social issues management will be provided.

**Environmental: Water Treatment II: Arsenic, Selenium and Other Contaminants****2:00 PM • Tuesday, February 17 • 106**

Chair: **S. Benowitz**, *Water Engineering Technologies, Inc., Bozeman, MT*

Sponsored by: **Violia Water Solutions**

**2:00 PM****Introductions****2:05 PM****Waste to Resource - Removing Metals, Sulfates & Nitrates for Reuse**

*K. McHale; Manufacturer, Hayden, ID*

Drought, over application of water rights and increasing demand for drinking water promote innovation in reuse and redistribution of resources between municipalities and industry. There is only so much water per state or region and cities, mining, O&G operations, food, farmers and others are all fighting for each drop. What one industry sees as waste could be another industries lifeline. Metals, non-metals and alkaloids, selenium, zinc, arsenic, mercury, fluoride, copper, molybdenum, even gold and silver can end up as dissolved constituents in industrial waters and can be treated to meet the strict permit requirements. Sulfate and nitrate can also be treated so water can be reused at the site or by others downstream. Systems to treat and remove these constituents will be discussed using coagulation, adsorption and filtration. This presentation will look at how one industrial facility with excess water can work with a nearby facility that doesn't have enough. Reuse needs to be looked at the state or region level, not just at the site anymore.

**2:25 PM****Cyanide Removal and Chemical Precipitation of Environmentally Problematic Metals and Metalloids from Gold Bearing Solutions**

*S. Billin, M. Spieth and S. Barton; Linkan Engineering, Elko, NV*

Removal of cyanide and environmentally problematic metals and metalloids in tailings water is a complex yet crucial industry consideration, as due to ever-increasing regulatory oversight implemented to safeguard downstream natural ecosystems, management of potential pollutants has become a primary concern. This presentation outlines a number of reduction methods in current use within the industry for the stated pollutants, and presents a case study in which various approaches were tested for effectiveness in a laboratory or at a pilot-scale to enable selection of the best overall mitigation process for the site-specific waters. This presentation cites the test data associated with each trialed method of contaminant reduction, as well as the cost of the industrial-scale process equipment and projected

annual operating expenses, and presents the methods that were ultimately selected for construction and use at the studied mine site.

**2:45 PM**

### **Field versus Laboratory Toxicity Testing, Metal Bioaccumulation and Use of the Metal Effects Addition Model to Identify Causes of Impacts Downstream of Two Mine Sites**

*H. Sonnenberg and L. Rozon-Ramilo; Environment, Stantec Consulting Ltd., Guelph, ON, Canada*

Significant impacts on benthic invertebrates and fish were found downstream of two mine discharges. Elements including As, Cd, Cu, Pb, Zn and Se were elevated in the surrounding water, sediment and biota. An integrated assessment of multiple lines of evidence including toxicity testing and modeling approaches was carried out to assess metal bioavailability and causes of toxicity on benthic invertebrate communities. Testing included extensive water and sediment chemistry, benthic community composition, toxicity testing in the laboratory and field using *Hyalella azteca*, metal bioaccumulation in wild, laboratory and field exposed *Hyalella*. Finally, the Metal Effects Addition Model (MEAM) and Biotic Ligand Models (BLM) were applied. The study addressed; what metals are causing toxicity in benthic communities? Do in situ field vs laboratory exposures reveal different toxicity and bioaccumulation results? Does the comparison of bioaccumulation data to Lethal Body Concentrations (LBCs) in the literature differ from results of the MEAM or BLM taking into account mixtures? Results of this study will also be used to assist with environmental management decisions at the site.

**3:05 PM**

### **Innovative Treatment Methods for AMD Applications**

*B. Housley; WesTech Engineering, Inc., Salt Lake City, UT*

Acid Mine Drainage (AMD) is perhaps the main environmental problem related to abandoned mine sites in the United States. Active treatment facilities utilizing neutralization, precipitation and sedimentation are necessary to treat low pH, elevated metal concentrations for mine sites with higher flow of ground water. This presentation will discuss key processes in the effective treatment of AMD such as exsolution of dissolved carbon dioxide with a pre-decarbonation stage, savings in chemical addition and solids disposal, improved treatment efficiency when incorporating the high density solids (HDS) process, and effective clarification design to provide quality effluent and thickened underflow. The improvements to this relatively simple process provide an effective treatment method to an age old problem.

**3:25 PM**

## **From Liability to Valuable Resource - Water Treatment and Management in Mining and Metallurgical Industry**

*M. Martikainen; Industrial Water Treatment, Outotec, Espoo, Finland*

In the past the water management in mining industry was considered to be only a costs generator to the business. However, nowadays water is recognized as a valuable resource that requires management. Waste waters in the mining industry are complex and always site specific. Typical impurities in mining industry waste waters are metals, arsenic, sulphate, chloride and cyanide. Due to complexity of the waste waters and high concentration of sometimes toxic impurities the company developing water management solution must be an expert not only on water treatment technologies but also on mineral processing technologies. When developing solution for the water treatment, one should keep in mind two targets. Treated water should have high enough quality so that it could be recycled in order to reduce water consumption. Secondly selected treatment process should be efficient and reliable so that the company can securely meet the requirements of environmental permits. There is a constant need for new treatment technologies that are not only efficient but also feasible. In this presentation latest developments in mine water treatment are presented.

## **Industrial Minerals and Aggregates: Health & Safety**

**2:00 PM • Tuesday, February 17 • 102**

*Chairs: E. Tarshizi, University of Nevada, Reno, Reno, NV  
J. Zdunczyk, Pike Industries, Inc., Westbrook, ME*

**2:05 PM**

## **Introductions**

**2:25 PM**

## **The Whole is Greater than the Sum of Its Parts: How Mining's Obsession with Rules and Regulations is Killing People (and what to do about it)**

*T. Boyce; Center for Behavioral Safety, LLC, San Carlos, CA*

Psychology can help your mine site create an effective Safety Culture and lead safety improvements. Still, many safety programs underutilize or mis-use the fundamental laws of human behavior to effectively prevent injuries. The result is a culture of compliance, complacency, and counter control by the very employees who should benefit from your safety program. In this fast-paced presentation, Dr. Boyce will draw from 20 years of personal experience applying psychology to prevent injuries and 120 years of behavioral science to describe how an em-

phasis on rule-following can be non-adaptive and what needs to be done instead. This session is appropriate for anyone with an interest in significantly improving safety performance.

**2:45 PM**

### **Safety: Stop and Think Let's Make it Personal**

*R. Johnson; Training & Development, Boart Longyear, Salt Lake, UT*

Why are the mining and oil/gas personnel still getting employees seriously hurt or killed. Are we getting comfortable in completing our task, are we complacent, should we be CHRONIC UNEASE. What are you doing to be safe at work and at home. Are you looking out for your coworkers, your family members, friends and neighbors? Let's make SAFETY personal. Let's STOP and THINK before we do a task. Let's be UNEASE about our daily tasks, looking for the possibilities of unsafe conditions. Let's go home to our families knowing we did everything we could to prevent incidents. STOP and THINK LET'S MAKE IT PERSONAL

**3:05 PM**

15-015

### **A Useful Tool for Predicting the Occupational Hearing Loss in Mining Industry**

*M. Li, A. Azman and J. Thompson; Hearing loss prevention branch, OMSHA, Pittsburgh, PA*

Powerful mining systems typically generate high level noise which can damage the hearing ability of the mining workers. Engineering noise controls are the most desirable and effective control for these noises. However, the effects on the actual hearing status of workers who use those noise controls are not easily measured. Furthermore, a guidance of assigning worker to a noisy environment for work, which can be used to reduce the risk of potentially damaging worker's hearing ability, is highly desirable. Therefore, NIOSH OMSHR developed a useful tool to estimate the hearing loss due to occupational noise exposure in a systematic way and evaluate the effectiveness of developed engineering controls. The developed software is based on the ISO 1999 standard and can be used to estimate the loss of hearing ability caused by the occupational noise exposures. In this paper, the functionalities of this software are discussed. Several case studies related to mining machines are presented to demonstrate the functionalities of this software.

**3:25 PM****Building a Safety Culture Through Mobile Technology, Business Intelligence and Process Change**

*P. Rogers, S. Dessureault and S. Gant; MISOM Technologies, Tucson, AZ*

Many processes and systems have been created to improve mine safety over the past several decades. Compliance to legislation and /or corporate safety standards results in increases of paper forms and data reentry. Advances in mine technology, such as, equipment health, ERP's, and operator fatigue monitoring has added to the potential safety data at mine sites. Meanwhile, the ubiquity of tablets, web-apps, and on-demand business intelligence is creating opportunities to both consume as well as create data digitally, further overloading practitioners. Data overload without prescribed processes and easy access to integrated data reduces the positive impact of initiatives. Modern Business intelligence and application of systematic processes can result in cultural transformations leading to improved safety. Even commercial-grade tablets can be used to capture and consume data in the field improving timeliness, data quality, and detail. Several case studies at a variety of mines is presented to show the benefits of a scorecard process and digital collection of safety data.

**Industrial Minerals and Aggregates: New Developments in Clay Minerals and Applications****2:00 PM • Tuesday, February 17 • 104**

*Chairs: B. Li<sup>1</sup>, Michigan Technological University, Houghton, MI  
R. Brown<sup>2</sup>, Rice University*

**2:05 PM****Introductions****2:25 PM**

15-075

**Fire Behavior of Kaolinite Composites**

*M. Batistella<sup>1</sup>, C. Petter<sup>1</sup>, B. Otazaghine<sup>2</sup>, R. Sonnier<sup>2</sup> and J. Lopez-Cuesta<sup>2</sup>; <sup>1</sup>UFRGS, Porto Alegre, Brazil and <sup>2</sup>Centre des Matériaux de Grande Diffusion, Ecole des Mines d'Alès, Alès, France*

Kaolinite is a dioctahedral aluminosilicate widely used as paper filler and coating pigment. In this study, the flame retardant effect of kaolinite in ethylene vinyl acetate copolymer (EVA) and polypropylene (PP) were studied and compared with an alumina trihydrate (ATH) and magnesium dihydroxyde (MDH). Cone calorimeter results shows that the weight percentage of ATH in EVA/ATH composites must be at least 50 wt. % in order to reach an improvement in fire retardancy in terms of pHRR. In the case of EVA/kaolinite, even with 35 wt. % the pHRR is largely reduced. Comparing PP/MDH and PP/kaolinite composites at 30 wt. %, both fillers leads to same reduction in pHRR with a

slightly better performance for PP/kaolinite. In both cases an intumescent behavior of kaolinite composites was observed that could slow the rate of the rising degradation products. Also, it was observed that kaolinite forms a protective layer on the surface of the samples, which could insulate the material. These behaviors (intumescence and formation of a protective barrier) could reduce the transfer of the degradation products to the flame and explain the better performance of kaolinite composites.

**2:45 PM**

### **Effect Study on the Rheological Properties of Mine Backfill Slurry with Clay Mineral Additives**

*X. Yang, G. Liu and L. Guo; Beijing General Research Institute of Mining & Metallurgy, Beijing, China*

In order to study the rheological properties of mine backfill slurry, two kinds of clay minerals (bentonite and one kind of inorganic self-flowing transportation admixture) had been used as the special additives. The basic physical and rheological parameters of these clay minerals were firstly tested, including graded composition, consistence and yield shearing stress. Then, taking an classified copper tailings for example, different dosages of two clay mineral additives had been mixed with the tailings to prepare a series of specimens in several concentrations. Besides, compared with the clay mineral additives, the fine particle tailings of this copper mine had also been used as an additive to make mixed samples and carry out rheological experiments with new Brookfield Rheometer. Based on the rheological parameters of the original unclassified tailings backfill slurry and analyzing the effect of additives on the mine backfill slurry quantitatively, the optimized mixture ratio to improve the rheological properties of mine backfill slurry had evaluated, and the mechanism of how these clay mineral additives improving the rheological properties had been given out respectively.

**3:05 PM**

### **Preparation and Evaluation of Polymer/Bentonite Filtrate Reducer**

*L. Zhang<sup>1</sup>, J. Zhang<sup>1</sup> and B. Li<sup>2</sup>; <sup>1</sup>Chemistry and Chemical Engineering, Xi'an Shiyou University, Xi'an, China and <sup>2</sup>Department of Materials Science and Engineering, Michigan Technological University, Houghton, MI*

This paper studied the preparation of polymer/bentonite filtrate reducer and their performance in drilling fluids. Acrylic acid (AA), acrylamide (AM), 2-acrylamido-2-methylpropane sulfonic acid (AMPS), and inorganic bentonite were used as raw materials. FT-IR, XRD, SEM, and TGA were employed to investigate the characteristics of the polymer/bentonite composite materials. The results showed that the polymerization occurred in the interlayer structure of montmorillonite, which led to a strip-like structure. The nanocomposites has a good thermal stability below 300°C. When P(AMPS/AA)/bentonite filtrate reducer added in fresh drilling fluid was 0.02%, the filter loss was 5.5mL, and it remained less than 10mL at 120°C of aging temperature. When its adding amount in 4% salt-solution drilling fluid was 0.05%, the filter loss was less than 13mL. When the addition of P(AMPS/AM)/bentonite filtrate reducer was 0.07%, the filter loss

in fresh drilling fluid was 6.8mL, and the filter loss in saturated salt-solution drilling fluid was less than 10mL, and kept stable during aging at 120°C.

**3:25 PM**

### **Characteristics and Extraction of Ti-bearing Blast Furnace Slag**

*H. Sun, G. Zhou, T. Peng and B. Liu; Key Laboratory of Solid Waste Treatment and Resource Recycle, Ministry of Education, Southwest University of Science and Technology, Mianyang, China*

Ti-bearing blast furnace slag is a unique secondary resource in Panxi region of China. A new approach for titanium extraction was studied in this paper. Iron-containing mineral was recovered by wet magnetic separation, then sulfation roasting followed by water leaching to extract aluminum and magnesium. The major compositions of the slag are CaO, SiO<sub>2</sub>, TiO<sub>2</sub>, and Al<sub>2</sub>O<sub>3</sub>, which existed in perovskite, diopside, and spinel, with totally 20.23% TiO<sub>2</sub>. With sulfation roasting followed by water leaching, the leaching rate of Al and Mg reached 87.39% and 90.59%, respectively. In the roasting process, (NH<sub>4</sub>)<sub>3</sub>H(SO<sub>4</sub>)<sub>2</sub> react with metal oxides in perovskite and diopside to form CaSO<sub>4</sub>. SiO<sub>2</sub> and TiO<sub>2</sub> were amorphous. Al<sub>2</sub>O<sub>3</sub> in spinel react with (NH<sub>4</sub>)<sub>2</sub>SO<sub>4</sub> and (NH<sub>4</sub>)<sub>3</sub>H(SO<sub>4</sub>)<sub>2</sub> to generate NH<sub>4</sub>Al(SO<sub>4</sub>)<sub>2</sub> which was further decomposed into Al<sub>2</sub>(SO<sub>4</sub>)<sub>3</sub>. Ammonia was used to separate aluminum and magnesium ions from the leaching liquid. The corresponding products containing more than 35% of titanium in amorphous anatase and perovskite were obtained. More than 90% of TiO<sub>2</sub> component in the titanium-rich products was extracted into sulfuric solution. TiO<sub>2</sub> powder was prepared.

**3:45 PM**

### **Discriminating Opaline phases from Cristobalite and Tridymite in Clays**

*G. Tomaino<sup>1</sup> and W. Moll<sup>2</sup>; <sup>1</sup>Minerals Technologies Inc, Easton, PA and <sup>2</sup>Moll and Associates, Lakewood, IL*

This talk centers on continued characterizations and evaluations of discrete Opaline phases and their association within clay matrices to discriminate an Opaline phase from that of regulated Cristobalite and Tridymite phases. Present regulations consider crystalline silica (quartz, cristobalite, tridymite) as "known human carcinogens". Opal-A, a silica hydrate, has a radial distribution pattern resembling the X-ray diffraction pattern of cristobalite such that many analysts and regulators confuse opal with cristobalite. Additional confusion arises with other the other opaline states opal-CT and opal-C. Historically, Jones and Signet proposed that these opaline states had progressively greater crystallinity. However, these categorizations may have overstated the inherent crystallinity of the given opaline structures which continues to this day in leading to confusion in mineral characterization for crystalline silica. To confirm a crystalline state specific to opal/opaline phases, a combination of known NIST reference materials (Quartz and Cristobalite) are used as internal standards to observe alpha to beta and beta to alpha transition states using Thermal-XRD and TGA-DSC/TGA-DTA.

**4:05 PM****Mineral-based Antibacterial Filler for Plastic Products***B. Li; Michigan Technological University and QTEK LLC, Houghton, MI*

Vermiculite is an extensively distributed natural mineral. In this study, vermiculite was implanted with copper and copper vermiculite, a new mineral filler with excellent antimicrobial property was prepared. Copper vermiculite powder was also embedded in polyethylene by extrusion and injection molding process, and antibacterial performance of polyethylene product containing copper vermiculite was quantitatively evaluated against *S. aureus*. The results shown that the treated plastics have been imparted antibacterial activity. The surface appearance of the plastics before and after the antibacterial treatment was also discussed.

**Mining & Exploration: Geology: Mineral Deposits II****2:00 PM • Tuesday, February 17 • 705***Chair: M. Haggerty, Barr Engineering, Edina, MN***2:05 PM****Introductions****2:25 PM**

15-008

**Vanadium Deposits in Arizona***T. Hammond; Hammond Swayne LLC, San Manuel, AZ*

Vanadium deposits in Arizona have been documented since the early 1900s. These deposits occur throughout the State and the main vanadium mineral is vanadinite, a chloro-vanadate of lead, commonly associated to the oxidation of lead sulphides in sedimentary rocks. Carnotite deposits similar to the ones in the Colorado Plateau have been identified in Apache County, in the north east part of the State. Although Arizona has not been a primary producer of vanadium in the past, it has the potential to become an important producer should the demand for this metal warrants. This paper describes the vanadium occurrences in the Zn-Pb-Mo-V deposits in the Miami-Globe, Dripping Springs and Mammoth districts.

**2:45 PM****Geotechnical Review of Existing Rock Pillars at the Former White Pine Copper Mine (Michigan)***M. Haggerty; Barr Engineering, Edina, MN*

The White Pine mine site in Michigan's Upper Peninsula is the location of a former copper mine operation consisting of room and pillar ground support. A portion of the mine was evaluated for possible reuse purposes. The evaluation included, radar scanning to determine existing geometry of the project area, field investigation to determine insitu stresses and rock properties, and finite element modeling to simulate stress changes in the existing pillars. Reuse requirements at the site may require some modification to the underground space which resulted in a need for the analysis. Determination of rock properties were performed through rock coring, point load testing, and laboratory testing. Modeling of the pillars was then performed using Midas GTS software. Existing conditions of the project area and proposed geometry modifications were simulated. This paper provides a description of the model geometry development, selection of input parameters, constitutive model selection, and stress state calibration.

**3:05 PM****Geologic Overview of Hydraulic Fracturing Sand in Wisconsin***K. Anderson; Kraemer Mining and Materials Inc., Burnsville, MN*

The mining of hydraulic fracturing sand in Wisconsin has proliferated rapidly over the past 5 years as the state has significant deposits of sand that meet the rigorous requirements of the oil and gas industry. Viable deposits of sand must be generally of pure quartz and highly rounded. Deposits must also be generally poorly to moderately cemented so as not to create significant clusters and must be generally free of silt and clay on the grains after processing. Additionally the deposit must have a sufficient percentage of sand grains in the desirable size range to be economically viable. The most utilized formations in Wisconsin are the Cambrian Jordan and Wonewoc. Careful geologic controls and consideration must be exercised during both identification of target sites and during production such that standards are met and product is viable for end use. The talkr will discuss the geologic overview of the utilized sandstones for hydraulic fracturing and geologic considerations for meeting specifications from his experience with the operation of 3 mines in Wisconsin and numerous exploration projects.

**3:25 PM****The Basal Jurassic Aramachay Formation in Central Peru: Facies Distribution, Palaeoecology and its Relation to Ore Formation**

*S. Rosas<sup>1</sup>, K. Ritterbush<sup>2</sup>, D. Bottjer<sup>3</sup> and F. Corsetti<sup>3</sup>; <sup>1</sup>Mining and Geology Engineering Department, Pontifical Catholic University of Peru, Lima, Peru; <sup>2</sup>Department of Geophysical Sciences, University of Chicago, Chicago, IL and <sup>3</sup>Department of Earth Sciences, University of Southern California, Los Angeles, CA*

Cherty dolomites and sedimentary structures of the Aramachay Fm in the central Western Andean Cordillera (WAC) of Peru indicate on-shelf deposition in contrast to black shale-rich/deeper water facies at the central part of the Eastern Andean Cordillera. The Aramachay Fm at WAC shows a siliceous sponge-dominated ecosystem. The role of metazoan biocalcifiers was profoundly reduced compared to the under- and overlying formations, representing an ecological state shift from preT/J-extinction carbonate to postT/J-extinction siliceous sponge dominated ecosystems before the carbonate system recovered. The Central Peruvian record is similar to that in Nevada, and is thus worldwide the second locality where this important event of siliceous sedimentation on epicontinental platforms is recognized in high stratigraphic resolution for the Early Jurassic. The T-J carbonates at WAC harbor a number of Miocene polymetallic replacement deposits. The cherty dolomites of the Aramachay sequence in this area hindered ore replacement acting as a trap or partial seal for ascending hydrothermal fluids through the underlying Upper Triassic more reactive rocks, in which developed most replacement ore bodies.

**3:45 PM****The Mineralogical Study of Ilmenites and Garnets as Indicators to Determine Whether the Tanoma Kimberlite Originated within the Diamond Stability Field**

*P. Cassidy; Geosciences, The Pennsylvania State University, State College, PA*

The Tanoma kimberlite is located in SW Pennsylvania within the Appalachian foreland basin, in a setting similar to dikes in Masontown and Dixonville, PA, Clear Springs, VA, and other localities in NY, KY and TN. Exposures of the kimberlite occur en echelon in the Lower Kittaning seam of Tanoma coal mine, where it is typically 38-46 cm thick and expands into the coal seam as ~4.5 m sill-like apophyses. Its age is expected to be 147 ± 5 Ma based on K-Ar dating on a nearby Masonville dike (Bikerman et al., 1994). The Tanoma is a type II porphyritic kimberlite with megacrysts (1-10cm) of phlogopite, Cr diopside, garnet, ilmenite, and enstatite. The matrix is comprised of serpentine, carbonate, and small phlogopite and Cr diopside crystals. Emplacement temperatures were ~494°C and 514°C as indicated by ~10 cm of coked coal adjacent to the dike and coke clasts within the kimberlite, respectively. Coal balls indicate the coal melted into a mesophase and deformed plastically. This study focuses on the composition of garnets and ilmenites to estimate the pressure/temperature conditions of generation and determine whether this kimberlite falls within the diamond stability field.

**International II****2:00 PM • Tuesday, February 17 • 108**

Chairs: **D. Malhotra**<sup>1</sup>, Resource Dev Inc  
**M. Gavrilovic**<sup>2</sup>, GR Engineering Services, Denver, CO

**2:00 PM****Introductions****2:05 PM****Impact of the New Tax Reform on Mexican Exploration and Mining**

*P. Williamson; Mexico/Central America, SRK Consulting (Mexico), Queretaro, Mexico*

A new Mexican tax code for mining was approved in October, 2013. The bill stipulates a 7.5% tax on sales, plus a 0.5% tax on gross revenue of gold, silver and platinum mines. The net result will be a decrease of 4 to 5% in cash flow after taxes. An additional fee was implemented on inactive mining claims, with increases of 50% after two years, rising to 100% over time. The long-term effects of the new taxes will hopefully be more apparent when the details are finally determined by the Mexican congress. Several of the largest mining firms threatened to divert investments to other markets when the tax was implemented. Many operating mines have stated that the new tax can be handled via tax strategies and will be no more onerous than the taxes in many other countries. The companies at greatest risk appear to be the small national companies that operate on very thin margins. As the details of the tax and its impact on the mining industry become clear, there will be shifts in the investment strategies in Mexico, the economic strategies of the operating mines, and the approach towards economic support of the communities surrounding a mine.

**2:25 PM****The Challenges of Mining in the Copper Belt of Africa**

*F. Danquah; Mutanda Mining SARL, Lubumbashi, Congo (the Democratic Republic of the)*

The Copper Belt reaches from the Katanga region of the Democratic Republic of Congo south to northern Zambia. It provides some of the highest grade copper deposits in the world. The "belt" provides a long and interesting history and challenges that differentiate it from other mining districts. This presentation will include an overview of issues surrounding mine development, logistics, community, social, and environmental issues.

**2:45 PM**

15-037

**Sustainable Mining in a Buddhist Country:  
The Case of Thailand**

*J. Kretschmann<sup>1</sup> and K. Sakamornsnguan<sup>2</sup>; <sup>1</sup>TFH Georg Agricola University, Bochum, Germany and <sup>2</sup>Institute of Mining Engineering I, RWTH Aachen, Aachen, Germany*

Sustainable development is an influential ethical concept in modern mining management. However, the concept is not culturally neutral because it is based on Christian, Western values. These values can be very different from traditional values in emerging mining countries like Thailand, where Buddhist values are dominant. When applying the concept of sustainable development, these differences should be taken into account. Different values imply different interpretations of 'good mining'. They have a significant impact on how mining operations are evaluated, perceived, operated, and managed. This paper attempts to integrate Buddhist principles with approaches of the sustainable development concept. When local values are appreciated and maintained, mining companies and their external stakeholders can identify objectives and approaches that suit to their own values and contexts. Practices based on this integrated ethic can help to promote sustainable mining and to minimize communication risks in mining countries like Thailand.

**3:05 PM****Mining Education in Peru**

*M. Cedron; Mining, PUCP, Lima, Peru*

Peru is an important mining country and the need of human resources for the list of coming projects is huge. How to recruit well prepared people at all levels, how to involve more and more people of the communities into the mining projects, how to educate Peruvians on the importance of mining and how to benefit from it at the most are key issues. This paper deals with these matters starting with mining education at universities and technical schools, but also on how the industry is addressing the issue of engaging community people into their projects and how also is the Peruvian population being educated into the importance of mining for the country.

**3:25 PM****Some Experiences Gained While Working as  
a Consultant in China**

*C. Moore; CW Moore Enterprises, Littleton, CO*

The presenter spent several months in China as a consultant and quality control supervisor on a 1,200 tonne steel construction project of conveyor belt galleries for a mining project in South America. He relates his experiences on delayed fabrication schedules, packing, shipping and lack of control by local engineers and supervisors, and from "lessons learned", and offers recommendations on how to improve the operation in a frank and honest fashion.

**3:45 PM****What is Old Is New; 200 Years of Copper Mining, Milling, Technology and History at Allihies Parish, Beara Peninsula, Cork County, Ireland**

*C. Anderson and L. Harris; Colorado School of Mines, Golden, CO*

The recorded mining history of the Berehaven Mines at Allihies began in 1812 with copper production initially from the Dooneen Mine. Thereafter, other mines such as the Kealogue Mine and Mountain Mine also began operation and soon made this region the largest copper production district in the world. This presentation will outline the history of this mining region and its mining and milling methods and technologies. Also, the socio-political impact on the region and its emigrated descendants who departed to mining regions such as Mt. Morgan, Australia and Butte, USA will be elucidated first hand based on a recent site visit by the co-authors.

**4:05 PM**

15-070

**Grain Structure Stabilized Backfill Material for HAW-Repositories in Underground Saliniferous Rock Formations**

*H. Mischo and S. Becker; Mining Engineering, Technical University Bergakademie Freiberg, Freiberg, Germany*

Grain structure stabilized crushed rock salt is a newly developed backfill material for infrastructural openings in HAW repositories. The motivation for this research is based on the fact that the grain structure stabilized crushed rock salt is superior to the currently used crushed rock salt. The avoiding of settlements with a simultaneous 100 % backfilling of openings, early stabilization of the geological barrier and low permeability ( $< 10\text{-}14 \text{ m}^2$ ) are the main improvements. By the newly developed backfill material, the gap between the crushed rock salt and the saliniferous composite backfill materials is closed. Due to the minimized amount of a binding agent, the material will still be easy to handle like a bulk material, but guarantees a 100 % backfill success without any settlements. This is reached by long-term stable re-mineralization that are formed by the components of the binding agent.

**Mineral & Metallurgical Processing: Comminution I: Comminution Circuit Design and Applications****2:00 PM • Tuesday, February 17 • 711**

*Chairs: A. Giblett, University of Utah, Subiaco, WAS, Australia*

*M. Dennis, FLSmidth USA Inc., Midvale, UT*

*Sponsored by: Moly-Cop USA, LLC*

**2:00 PM****Introductions****2:05 PM**

15-065

**Chile's Sierra Gorda Cu-Mo Mine**

*T. Comi; Technical Services, Sierra Gorda SCM, Sierra Gorda, Chile*

The Sierra Gorda SCM sulphide ore processing plant was commissioned in the third quarter of 2014. Located in the Atacama Desert in northern Chile, the project is a joint venture partnership with KGHM International (owned by KGHM SA, Poland), Sumitomo Metal Mining, and Sumitomo Corporation (Japan). The Sierra Gorda open pit mine and copper-molybdenum processing plant will become one of the largest, most highly-instrumented operations in the world. It is the first hard rock operation in Chile and the second in South America to utilize HPGR technology. It is a significant Molybdenum resource especially in the first five years and the Molybdenum separation plant, designed to process up to 60 million lbs. of fine Molybdenum per year, is complex, providing the latest technology and equipment to ensure superior recovery and product quality. This paper discusses the overall operation and issues relating to the concentrator start-up.

**2:25 PM****A Guide to the Citic SMCC Approach Using Modelling and Simulation for the Design of Comminution Circuits**

*E. WANG, S. Morrell and J. Tian; CITIC SMCC Process Technology Pty Ltd, Brisbane, QLD, Australia*

CITIC SMCC has developed a comprehensive system for the design and optimisation of comminution circuits, which is primarily based on the broad range of comminution simulation models developed by Dr. Stephen Morrell and validated against CITIC SMCC's large industrial database generated by over 150 operating plants around the world. Besides circuit design and mill sizing, now the system has incorporated the full functionalities of mass balances for various flowsheet configurations as well the process optimisation tools, through a third party platform. Various circuit configurations are structured to allow the equipment models to combine together to describe the performance of each circuit being studied. The circuit models can then be used in simulation mode to predict "what if" scenarios. This simulation approach allows wide range potential circuit configurations to be investigated within the known limitations of the circuit and unit process models as trade-offs during plant design.

**2:45 PM****The Performance of the Newmont Akyem Gold Plant Comminution Circuit**

*D. Annandale<sup>1</sup>, J. van Huyssteen<sup>2</sup> and C. Brits<sup>3</sup>; <sup>1</sup>Technical Services, Newmont, Englewood, CO; <sup>2</sup>Technical Services, Newmont, Englewood, CO and <sup>3</sup>Akyem Processing, Newmont Ghana, New Abirem, Ghana*

Newmont recently completed the construction of its second gold processing facility in Ghana, the Akyem Gold Plant, located approximately 230 km by road from its other operation, the Ahafo Gold Mine, which has been in operation since June 2006. Construction on the Akyem processing facility and associated infrastructure commenced in March 2011. The mining of the single open pit commenced at the end of August 2012 and the processing facility was commissioned and started-up at the end of August 2013. Commercial production was achieved in October 2013. The processing facility comprises of a 25,500 tonnes per day SABC comminution circuit and CIL leach circuit. This paper discusses the start-up and operation of the comminution circuit for the first year, with particular emphasis on actual performance against modeled performance.

**3:05 PM****IsaMill Design for Ultrafine and Regrind Applications**

*M. Larson and M. Young; Glencore XT, Brisbane, QLD, Australia*

Glencore XT has certified laboratories around the world to do grinding scale up work for the design of industrial size IsaMills. The tests are proven to provide 1:1 scaleup with no adjustment factors provided the correct procedures are followed. Some precautions and general rules of thumb for the few adjustable conditions have been developed through two decades of experience. The laboratory/pilot process will be discussed along with modelling tools for the design and optimization of full scale IsaMills.

**3:25 PM****Ball Mill Noise Reduciton,**

*D. Perin; H&DE, Aearo Technologies, LLC a 3M company, Indianapolis, IN*

In a recent application, 3M responded to a customer request to quiet operations of ore-crushing ball mills. The huge cast steel cylindrical drums are loaded with "76 mm" steel balls & ore and are rotated at low speed. The ore crushing ball mills operated in a sheet steel structured shed building with considerable reverberation times. Rather than treating the building shed as is typically done, 3M innovated by attacking the problem at the source, the ball mill. Successfully treating the noise emissions from the mill required a thorough assessment, then solution modeling and application of vibration damping and isolation materials. The engineered acoustic solution made a significant decrease in ball mill noise resulting in an environment noise reduction of up to 5 dBA. In addition, the solution employed is proving significantly more durable than the traditional noise blankets or curtain typically used.

**3:45 PM****The Effect of Feed Fines Content on the HPGR Performance***S. Rashidi and R. Rajamani; University of Utah, Salt Lake City, UT*

High Pressure Grinding Rolls (HPGR) technology is the continuous version of the confined particle-bed breakage. Feed size distribution has a key role in total specific energy consumption and product size reduction. Fines in the HPGR feed are defined as relatively small particles that should not undergo much breakage while assisting the breakage of larger particles. Extensive testwork has been performed on a 200 mm by 100 mm lab-scale HPGR at the University of Utah on different ore types. Various artificial feed size distributions have been prepared by mixing large narrow-sized particles as the main portion of the feed and different sizes and percentages of fines to complete single-pass and closed-circuit tests. The effect of the fines content is evidently dependent upon the size ratio between the feed main portion and the fines. In addition, fine particles help with better energy transformation in the grinding zone to a specific level depending on the size for the feed main particles. The presence of the fines in the closed-circuit configuration helps with improving the breakage rate and the total energy consumption when compared with closed-circuit grinding on a narrow-sized feed.

**4:05 PM****A Closer Look at Increasing HPGR Efficiency via Reductions in Edge Effect***B. Knorr<sup>1</sup>, V. Herman<sup>1</sup> and D. Whalen<sup>2</sup>; <sup>1</sup>Metso, York, PA and <sup>2</sup>Freeport-McMoRan Inc., Phoenix, AZ*

Edge effect is the widely observed condition of impaired comminution performance at the edges of High Pressure Grinding Roll (HPGR) tires. This effect is caused by a reduction in the local crushing pressure at the edges of the tires resulting from the interaction between the static cheek plates and HPGR feed material. In open circuit operations, this effect results in coarser particles reporting to downstream equipment. In closed circuit applications, edge effect results in an increased circulating load and diminished HPGR circuit capacity. Results will be presented to demonstrate how edge effect was significantly reduced through innovations in the Metso HRC™ HPGR design, which incorporates an Arch-frame and a flanged tire design. Through a series of pilot plant tests comparing a 750 mm x 400 mm HPGR with flanges versus the same HPGR with traditional cheek plates, the enhanced performance when operating with a flanged tire design are demonstrated. A detailed description of the pilot testing protocols, results and analysis are presented. In addition, insights into the implications for circuit design, energy efficiency and overall plant performance are also presented.

**Mineral & Metallurgical Processing:  
Plant Design and Optimization****2:00 PM • Tuesday, February 17 • 708***Chairs: S. Holmes, Freeport McMoRan Inc, Morenci, AZ  
D. Meadows, FLSmidth, Phoenix, AZ***2:00 PM****Introductions****2:05 PM**

15-112

**Impact of ROM PSD on the Crushing and Grinding Circuit Throughput***T. BoBo<sup>1</sup>, J. Kemeny<sup>2</sup>, F. Fernández Romero<sup>4</sup> and M. Rocha Gil<sup>3</sup>; <sup>1</sup>Split Engineering, Tucson, AZ; <sup>2</sup>University of Arizona, Tucson, AZ; <sup>3</sup>Rocha Blast Engineers, madrid, Spain and <sup>4</sup>Split Engineering Chile, Santiago, Chile*

Mathematical modeling in conjunction with mineral characterization is widely used as a method for design and optimization of comminution circuits, to simulate the processes of crushing, grinding and classification. An important input parameter to the simulation models is the Run-of-Mine Particle Size Distribution (ROM PSD). The run-of-mine size distributions due to blasting have a great influence on the performance of a SAG mill. In this paper, a mine case study was conducted where there are four primary geologic units and the material properties between the four units vary considerably. Also, the mixture of the four unit that will be mined at any given time also vary considerably. This presents a challenge in terms of optimizing the blasting for mill production throughout the mine life. As part of the case study, field rock mass characterization, laboratory rock mechanics tests, and laboratory breakage tests were conducted. The field characterization and rock mechanics tests provide material properties used to simulate the effect of different blast designs on run of mine particle size distributions (ROM PSD).

**2:25 PM****Plant Asset and Energy Optimization: the calming cloud over the operations***O. Bascur<sup>1</sup> and M. Halhead<sup>2</sup>; <sup>1</sup>OSIsoft, LLC., Houston, TX and <sup>2</sup>AngloAmerican, Johannesburg, South Africa*

Large mining and metallurgical complexes have more data than a small city and much it is in “real time”, changing rapidly as internal and external conditions evolve. As corporations buy and sell assets and reengineer their staff, the structure and tools that were used to understand these data are lost. This results in significant deterioration in the ability to maintain a “smart” operation. In many situations, all partners in a business collaboration – such as joint ventures, contract manufacturers, expert service providers, and operations and maintenance companies – need access to production and asset data. PI Cloud connect provides all parties a secure way of sharing data between their

respective PI Systems without having to deploy point to point VPNs. This presentation will share examples of how mining and mineral processors have adopted new strategies such as self-serve business intelligence, cloud computing and internal/external collaboration. Mine and mill asset availability and drastic reductions in operating costs examples will be presented.

**2:45 PM**

### **Contemporary Plant Design: A Performance and Cost Comparison of Materials Used in Construction of Hydrometallurgical Equipment**

*K. Lambrych; Specialty Resins, Ashland Performance Materials, Dublin, OH*

Materials for plant equipment design and fabrication are selected based on a combination of their ability to perform as required in the corrosive environment of hydrometallurgical processes as well as their cost. Recently, as the price of nickel has increased, so has the cost of alloys capable of meeting corrosive acid leaching processes for copper, cobalt, nickel, uranium, and rare earth elements. Equipment fabricated using Fiber Reinforced Plastic (FRP) has been shown to be capable of withstanding the aggressive environment of these processes. This paper will compare the performance and cost of plant equipment fabricated with stainless steel alloys and FRP made with Epoxy Vinyl Ester thermoset resins. Case histories where FRP has been used to fabricate piping, storage tanks, extraction vessels, and electrowinning cells will also be reviewed

**3:05 PM**

### **Recovery Improvements from Start-up of the Mount Milligan Mine**

*P. Miranda; Thompson Creek Metals, Denver, CO*

The Mount Milligan Mine, owned by Thompson Creek Metals Corporation (TCM), started production in August of 2013. It has a 22 year mine life with 2.1 billion pounds of copper and 6 million ounces of gold in reserves. It is currently the 2nd largest gold mine in Canada. Like all start-up operations, there have been some issues. Because of this, several parameters have been laboratory tested with changes resulting in the mill to increase recoveries and throughput. The changes include frother testing, grind size testing, reagent dosage testing, and ore testing. From the testing, improved throughput and overall recovery of gold and copper has been achieved, however, additional testing is currently being implemented for further improvement. This paper will discuss the history of Mount Milligan, grind, frother and reagent testing along with results from the mill and laboratory data.

**3:25 PM****Alkaline Sulfide Leaching of Enargite***D. Alcorn, J. Longacre and C. Anderson; Kroll Institute for Extractive Metallurgy, Colorado School of Mines, Golden, CO*

As traditional high grade copper resources are depleted, processing of unconventional complex lower grade resources becomes necessary. For example, enargite is a common copper sulfide ore with high amounts of arsenic. The arsenic can cause environmental problems when the concentrate is processed at a smelter. Hence, due to the increase in demand for copper containing products, there is a need to effectively process more complex ore bodies. In this study, industrial alkaline sulfide leaching was used to treat an enargite concentrate. After the concentrate has been leached, it can be sent to a copper smelter with greatly reduced penalties and a more favorable smelting contract due to the mass reduction. To build a leaching circuit to treat the concentrate would require a capital investment of about \$50 M USD and would offer (before taxes) a 9 month payback period. Over a 15 year life, an NPV of about \$500 M USD at an 8% discount rate and an IRR of over 130% are expected. This project confirms that an alkaline sulfide leach is an applicable, economical and environmentally friendly method to remove arsenic and antimony from copper enargite concentrates.

**3:45 PM**

15-140

**Managing Cyclones: A Valuable Asset.  
The Copper Mountain Case Study***M. Westendorf<sup>1</sup>, D. Tinney<sup>1</sup>, T. Banerjee<sup>2</sup>, M. Schaffer<sup>2</sup> and S. Kaushik<sup>2</sup>; <sup>1</sup>Copper Mountain Mining Corporation, Princeton, BC, Canada and <sup>2</sup>Portage Technologies Inc., Toronto, ON, Canada*

The Copper Mountain Mine is located in Princeton BC, Canada and produces 80 – 90 Million lbs of copper, plus gold and silver by-products annually. The plant has a conventional SAG/ Ball circuit followed by flotation. At most plants, much time is spent evaluating and optimising the comminution and flotation circuits. The cyclones are a key contributor to the effective operation of the plant. If the cyclones are not performing as they should, the results are often a combination of lost recovery, lost grade, reduced throughput and lost capacity in flotation. For such an impactful unit operation, cyclones have historically been under-instrumented. Copper Mountain Mine recognised the critical role that cyclones filled in their plant and worked to optimise them through the implementation of a Portage Cyclone Detection (PCD) system to identify plugging and roping incidents, Portage Pumpbox Control (PPC) to manage the flow to the cyclones and AwaRE to control the circuit. As a result, cyclones overflow stability has increased, switching out a roped or plugged cyclone now happens within seconds rather than many minutes and both the grinding and flotation circuits perform better.

**Mineral & Metallurgical Processing:  
Remediation and Secondary Processing:  
Secondary Processing****2:00 PM • Tuesday, February 17 • 712**

Chairs: **L. Schlink**<sup>1</sup>, Freeport-McMoRan Copper & Gold, Oro Valley, AZ

**B. Erfourth**<sup>2</sup>, Barr Engineering, Minneapolis, MN

**2:00 PM****Introductions****2:05 PM****Powerful Recent DEMET Technical  
Advancements**

*P. James and M. Baker; Blue Planet Strategies, Madison, WI*

Significant technical advancements to BPS's versatile electrolytic DEMET dilute source metal recovery and concentrating technology have been made in the last year and their implications are discussed. Specialized electrodes and a range of separators for controlling the detailed process chemistry and allowing significant new process refinement are available for site-specific and scenario-specific system customization. Improved dynamic electrode activation was developed and brings powerful practicality improvements including: improved system layout geometry adaptability, simpler and fewer potential failure points, ready isolation for repair and/or capacity adjustment, easier capacity scaling, improved fouling resilience to potentially fouling elements, and leveraging of familiar components for easier O&M and better suitability to existing operator/maintenance skills and equipment. The impacts of these advancements along with representative results illustrating DEMET performance and range of utility for a variety of chemistries will be presented.

**2:25 PM**

15-139

**Moly Processing Leach Optimization**

*R. Edwards and J. Andres; Freeport McMoRan, Green Valley, AZ*

Freeport-McMoRan's Sierrita Operations refines molybdenum disulfide in a Ferric Chloride leach to remove impurities. To understand bottlenecks in the leach process and the true capacity of the leach system, a cross-functional team was established to look at theoretical models, kinetics of the leaching process, equipment limitations and operational strategies. A series of in-plant tests were run which resulted in a road map for improved throughput.

**2:45 PM**

15-003

**Moly Processing Roast Optimization***M. Cross and J. Andres; Freeport McMoRan, Green Valley, AZ*

Freeport-McMoRan's Sierrita Operations has two natural gas-fired molybdenum roasters for converting molybdenum disulfide into molybdenum trioxide. When these roasters were compared to other similar units within the company during a benchmarking exercise, it showed that increased throughput from the roaster units at Sierrita was possible. A team of site metallurgists, technical experts from other sites, and engineers from the Climax Technology Center was formed to study the potential in more detail. The team investigated many parameters in the roaster, including temperature profiles, roaster chemistry profiles, rabble and drop hole patterns, and operational strategies. The results of these studies and the associated throughput improvements are described in this paper

**3:05 PM**

15-126

**Effects of Seeding Strategies Through Recycled Crystal Classification on Crystal Size Distribution (CSD) for Copper Sulfate***J. Liu; Hydromet, Freeport McMoRan, Green Valley, AZ*

The Freeport-McMoRan Crystal Plant produces Copper Sulfate Pentahydrate through a series of cooling crystallizers. In this process, inevitable continuous nucleation and unwanted spontaneous nucleation promote fine crystals. Therefore, seeding through recycled crystal classification is critical to manipulate the CSD for coarser crystals. Seeding requires an understanding of the particle size, solution temperature and amount of crystals that go into the crystallizers. Knowledge of the cut off fines size is important for fines dissolution. Proper selection of the crystallizer can avoid unwanted spontaneous nucleation from cooling in the unstable zone. The industrial crystallizer typically operates at suspension densities between 15% and 25%. Validation of the current suspension densities and determining the amount of seeding will also be investigated to promote the final crystal size. This study will discuss the overall crystallization process, impact of seeding, fines dissolution on CSD and the findings on the investigation of seeding strategies.

**3:25 PM**

15-071

**Material Parameters and Their Influence on the Behavior in Back-filled Masses***H. Mischo and F. Schreiter; Mining Engineering, Technical University Bergakademie Freiberg, Freiberg, Germany*

One method of increasing the exploitation rate of a mine is the use of backfilling with re-sidual materials in exploited mining areas. The backfilled material is meant to support both the walls of galleries and pillars as well as the roof of mining openings. With increasing depth, the exploitation rate is diminishing fast,

thus the application of back-fill in order to change the layout of the mine is crucial for economic success. In result it is possible to change the layout of the working area with more excavated areas and less area occupied by pillars. It is possible to boost the output of a mine using backfill. Setting the criteria for the selection of the best possible materials and whose improvement, it is useful to know about their qualities and handicaps. For this study, the Mining Institute at TU Bergakademie Freiberg is analyzing the parameters of residues from different processing methods, accrued in plants of different potash mines and blending different residues for optimization of material attributes. These were significantly characterized by very basically parameters like the size and the distribution of the different diameters and the material of the grains.

## **Mineral & Metallurgical Processing: Separation: SX/IX/EW**

**2:00 PM • Tuesday, February 17 • 710**

*Chair: B. Hutzler, Cytec Industries, Tempe, AZ*

**2:00 PM**

### **Introductions**

**2:05 PM**

### **The Effect of Commercial Electrowinning Additives on the Nucleation and Growth of Copper on Stainless Steel**

*A. Luyima, W. Cui, C. Heckman and M. Moats; Materials Science and Engineering, Missouri University of Science and Technology, Rolla, MO*

Nucleation and growth of copper on 316L stainless steel from synthetic acidified copper sulfate was studied in the absence and presence of chloride ions, organic additives (HydroStar 4208, DXG-F7, Cyquest N-900) using a potentiostatic technique. The current-time data obtained at different conditions was analyzed using nucleation and growth models in literature in consult with a scanning electron microscope (SEM). SEM images show that addition of 20 mg/L chloride increased the size and reduced number of nuclei. The current-time data from the electrolyte without organic additives indicate progressive nucleation with two-dimensional (2-D) growth under diffusion control. However, SEM images obtained at similar conditions indicated progressive nucleation with a combination of 2-D and 3-D growth. 20 mg/L Cl<sup>-</sup> and 2.5 mg/L organic additives did not change the nucleation and growth mechanism. Organic additives did increase the number and reduced the size of copper nuclei. The organic additives produced smoother deposits in two hour electrowinning experiments.

**2:23 PM****Evaluating the Effects of Flow Rate and Concentration Changes on Copper Ore Heap Leaching***M. Free; University of Utah, Salt Lake City, UT*

Heap leaching of copper ore is influenced by a variety of application factors. Among the most important factors are flow rate and concentration. In many operations, concentrated solution, such as sulfuric acid, is added to the ore prior to placement on the heap leaching pad. The concentration of acid addition prior to placement and during subsequent leaching solution application has an influence on leaching performance and on the concentration of copper and pH of the leaching solution. In addition, the flow rate of solution applied to the heap can be varied to enhance overall performance, control product delivery, or to modify solution circulation or heap temperature. This presentation will discuss effects of changing concentration and flow conditions on leaching parameters and performance.

**2:41 PM****Liquid-Liquid Solvent Extraction of Ferric Ions from Electrolyte Solutions***J. Bender and N. Emmerich; BASF Mining Solutions, Tucson, AZ*

One of the most transparent losses in the copper solvent extraction-electrowinning (SX-EW) system is the bleeding of copper rich electrolyte from the electrowinning system in order to control iron concentrations. Iron is transferred from the pregnant leach solution (PLS) to the EW circuit either as entrained aqueous in the organic phase or by chemical extraction of ferric ions. A minimum amount of iron is necessary in electrowinning solutions for various reasons such as the control of manganese. However, as the concentration of iron is raised the redox reaction of ferric and ferrous ions at the cathode and anode starts to consume current which results in the reduction of current efficiency. BASF has completed and field tested a solvent extraction process for the control of iron in the electrolyte. This process removes ferric ions selectively and sends the electrolyte back to the EW system without interfering with the cobalt, mist suppression, or smoothing agent concentration.

**2:59 PM**

15-116

**POLYSIL<sup>®</sup> Coagulants to Improve SX Conditions – A Practical Way to Reduce Colloidal Silica and Crud Formation***A. Smethurst, S. Boskovic and S. Hearn; Performance Products, Huntsman, The Woodlands, TX*

The digestion of minerals in strong acids or at elevated temperatures can result in the release of large amounts of silicic acid which can polymerize in solution to form colloidal silica and gels. Colloidal silica can cause a number of problems including interfering with flocculation, initiating crud formation in solvent extraction (SX), decreasing SX extraction kinetics and increas-

ing SX phase disengagement times. Huntsman's POLYSIL® polyether coagulants have a "lock and key" relationship with the surface of colloidal silica to help lower the concentration of these particles in solution, improve process efficiency and reduce reagent losses by minimizing crud formation. This paper investigates some of the issues caused by colloidal silica in hydrometallurgy processes and illustrates how the use of POLYSIL® coagulants has helped to improve process outcomes.

**3:17 PM**

15-103

## **Chloride Management in Copper Solution Extraction Process**

*C. Everly; Hydromet, Freeport McMoRan, Green Valley, AZ*

The purpose of this paper will be to review the most effective methods of reducing chloride transfer and chloride removal in the SX/EW process. Elevated chlorides in the electrolyte has various negative effects including a reduction in current efficiency, increased handling costs at rod plants and smelters, increased anode corrosion, cobalt losses due to increased electrolyte bleed, degradation of HDPE piping and increased corrosion in the SX/EW plants. Historical controls that Sierrita has used to control chloride transfer, in order of effectiveness, have been chloride gasification at the EW that is directly correlated to amperage and chloride concentration in electrolyte, wash stage bleed and efficiency, width and velocity of aqueous bands, and electrolyte bleeds. Maintaining high bleed rates and high amperage settings has been a challenge with decreasing PLS grades, so keeping chlorides out of the electrolyte has become imperative. The effectiveness of reducing aqueous entrainment, optimizing mixer speed and wash stage efficiencies, and improving organic quality to reduce the transfer of chlorides to the electrolyte will be illustrated in this study.

**3:35 PM**

## **Future Possibilities of Modularization in Mining Industry**

*R. Saario, R. Saario and H. Fredriksson; Outotec, Espoo, Finland*

Mining industry is facing many challenges such as declining grades and remotely located deposits with lack of infrastructure and shortage of labor. In addition, future commodity price uncertainty makes investment decisions difficult. Modularization principles offer solution to reduce the uncertainty. Still, suitability of modularization is often questioned. Modularization is perceived to include complex engineering phase as well as increased overall cost of the project. Typically, modularization has been only applied to the most extreme cases. Outotec's approach is to simplify the engineering, shorten lead time and decrease the capital costs of projects through use of standard modules. The paper evaluates modularization benefits in mining industry by examining the modularized Outotec VSF®X SX Plant. This case study argues the possible benefits for the whole mining industry. The results indicate that modularization can improve mining operations. Important aspects are the control of module size and the standardization of modules in order to

achieve scalability. Prefabrication of modules is another key element to cope with uncertainty which is faced in current mining projects.

**3:53 PM**

15-108

**Clay Treatment Improvements using ACORGA® CB1000**

*B. Hutzler, C. Cooper, A. McCallum and T. McCallum; Cytec Industries, Inc., Tempe, AZ*

In copper solvent extraction, managing the quality of the organic phase is a key parameter to ensure optimal physical and metallurgical performance in the plant. Increased throughput as a result of declining ore grades coupled with advances in plant design and practice, resulting in reduced organic losses, has pushed the limits of the status quo with respect to organic quality. Clay treatment of plant and recovered organic at the optimal dosage is critical in maintaining quality, however, achieving the optimal dosage through existing filtration capacity and practice can be difficult. Cytec has developed a process aid that increases efficiency of existing filtration equipment that has been successfully implemented at two commercial SX operations. ACORGA® CB1000 enables higher dosages of clay while allowing for more efficient use of existing filtration capacity. This study analyzes results from commercial trials and demonstrates that improved organic quality and clarity is achievable through optimization of current treatment practices.

**Mining & Exploration: Management:  
Mineral Economics****2:00 PM • Tuesday, February 17 • 706**

*Chair: R. Barickman, Eagle Mine, Marquette, MI*

**2:00 PM****Introductions****2:05 PM**

15-032

**The Impact of a Strong Local Supply Chain on Regional Economic Impacts of Mining**

*M. Xing<sup>1</sup>, K. Awuah-Offei<sup>1</sup>, S. Long<sup>2</sup> and S. Usman<sup>1</sup>; <sup>1</sup>Mining & Nuclear Engineering, Missouri University of Science & Technology, Rolla, MO and <sup>2</sup>Engineering Management, Missouri University of Science & Technology, Rolla, MO*

While mines generally focus on achieving operational efficiency, creating shared value for all stakeholders is also a management goal. This includes taking a holistic view of their supply chains and increasing local participation. This paper examines the role of supply chain management in mine management; in particular

the effect of a strong local supply chain on regional economic impacts. Using input-output analysis, impact of a local supply chain on a mine's regional economic impact is examined, with four different levels of local sourcing. The impacts examined are sales, employment, labor income, and taxes. This work can provide insight on how to better create shared value for local stakeholders.

**2:25 PM**

### **Development of a Mine Planning Approach for Copper-Gold Producer to Timing Capital Investment Using Option Valuation Model**

*B. Perez; Mine Technical Services, Newmont Mining, Greenwood Village, CO*

Price of copper and gold will perform stochastically during a Life of Mine (LOM). Mining engineer's methodology is to avoid that variability using a "long term price" for the commodities. This is a deterministic value based on the 3-year average price for copper and/or gold. Mine plans and reserve estimations are mostly calculated at those prices to assure that the mine in the long run is profitable. Using the "average" price will be misleading of any future mine and/or mill capital investment on expansions. This research uses a different method to incorporate price commodities variability on a valuation of a mine and at the same time uses that to justify capital expenditure. The researched method is incorporating extra capacity at the mine or the mill to add value to the mine plan. Then incorporating a "real option approach" to predict best timing to expand the mine and/or mill when is appropriated resulting in an more real value of the mine.

**2:45 PM**

### **Social License, Big Data, and the Economics of Mining Permits**

*P. Rogers<sup>1</sup> and S. Dessureault<sup>2</sup>; <sup>1</sup>University of Arizona, Marana, AZ and <sup>2</sup>MISOM Technologies, Tucson, AZ*

The economics of obtaining mining permits has been transformed by outward social pressures. Social license, societies' "permission" to operate, and maintenance of a positive public image are crucial for a project, company, or industry to exist. Mining permits are increasingly being stalled, delayed or outright rejected by political entities due to stakeholder pressures. The internet and social media are transforming definitions of stakeholders and methods of engagement. Sustainable development intelligence related to "big data", such as internet and social media interaction; socioeconomic indicators; water/energy consumption; and many others, can help the industry respond proactively to these changing times. Big data and systematic processes to use information can be a powerful change agent for companies and the mining industry. These solutions can also provide the analytic framework for successful stakeholder engagement and modeling the risks/economics around permitting new mines.

**3:05 PM****Mineral Economics Education in 2015***D. Hammond; Hammond International Group, Highlands Ranch, CO*

Mineral economics as a defined field of study and area of professional practice became established following World War II. A number of university programs were established in subsequent decades but most have disappeared. This presentation provides a global census of formal mineral economics education venues past and present, and examines the currently active ones from both academic and applied perspectives. Observations are made regarding the practical value of such programs to the modern mining industry.

**3:25 PM****Application of Six-Sigma & Correlation Coefficient Techniques to Improve Economic Performance of an Underground Operation***O. Tovar; Mining, Ingeniería de Recursos SRL, Lima, Peru*

There is a usual behavior when metal prices shrink in a mining operation, and it is represented by the compulsive need to cut costs jeopardizing the stability of the operation. This is most of the times explained because of the lack of an integrated numerical perspective of the weights that each economic variable add to the operation. In this paper, it will be represented a complete Value Stream Map Analysis, considering the 5 main Value Process in the operation: Exploration, Development, Mining, Plant, & Trading. Each of these have their own critical variables with defined stochastic behavior that will be fed in an economic model to determine -using Correlation Coefficients- an inter-process ranking of the most critical variables to then apply Six-Sigma tools to improve the economic performance. Variables such kurtosis, meters per face/crew, meters drilled, met recoveries, costs, trading terms, etc will be used in an Excel-@Risk based model to target and define the most effective route to improve economic performance, or to deal with sudden metal prices melt, in order to decide either reduce cost, increase output, or mix a capital-production strategy to overcome a crisis.

**3:45 PM****Mining, Oil, and Income Inequality***G. Davis; Economics and Business, Colorado School of Mines, Golden, CO*

It is commonly presumed that economies specializing in mining and oil supply have high income inequality. The research testing this proposition is sparse, and the tests that have been undertaken are missing inequality data for the majority of mining and oil economies. This paper makes use of several new data sets that are comprehensive in their coverage of inequality in mining and oil economies to test the proposition that these economies have unusually high income inequality. The results in some cases confirm but in other cases refute the proposition, with the outcome depending largely on how mining and oil economies are defined and which countries are in the sample. On the whole, no general statement can be made regarding mining and oil extraction and income inequality. The result is important not

only for the direct implication for extractive activity and social welfare, but it also implies that extractive economies are not doomed to slower growth as a result of high income inequality. The mining industry should embrace this result in its promotion of mining as a path to economic development.

## **Mining & Exploration: Operations: Hard Rock Open Cut**

**2:00 PM • Tuesday, February 17 • 502**

*Chairs: A. Briggs<sup>1</sup>, Tetra Tech, Aravada, CO  
R. Rojas<sup>2</sup>, Freeport McMoRan, Tucson, AZ*

**2:00 PM**

### **Introductions**

**2:05 PM**

### **Analysis Tools for Managing Mining Truck Payload to Optimize Production and Cost**

*J. Ingle; Mining Trucks, Caterpillar Global Mining, South  
Milwaukee, WI*

Because haulage is the major driver of earthmoving costs in a mine there is always pressure to increase productivity and reduce cost by overloading. But if not managing and tracking other factors and costs the result is often only an improvement in payload and not overall production or lower cost per unit volume moved. This paper covers the types and sources of data to use and actual field examples of analyzing the data. This includes statistical analysis of frequency histograms and distributions along with examples of how to evaluate payload, load time and cycle time through payload “bins”. In addition the paper shares tactics and field results that can help improve payload through reducing the standard deviation and shifting the average up.

**2:25 PM**

### **A Two-Stage Model for Metal Mining and Stockpiling Management**

*K. Zhang; Energy and Mineral Engineering, Penn State  
University, University Park, PA*

For a metal mine, the intermediate grade ore between economic cutoff grade and breakeven cutoff grade is stockpiled for future processing after the mine is depleted. This research establishes a theoretical two-stage mining model with production from the stockpiled ore. By deriving the first order conditions of objective profit function and parameterized analysis, this research finds that the profit from processing the stockpiled material can significantly boost a mine’s profit; inspecting the stockpiled material shifts the choice of the optimal production rate and cutoff grade strategy; the research also measures how responsive the optimal mining rate is to the changes in input variables such as metal price, total material quantity, processing capacity, etc.;

the impacts of some variables diminish as the percent of change increase. The intrinsic advantages of the theoretical model compared to numerical methods in explaining the economic intuition of stockpiling management and optimal mining strategy are discussed

**2:45 PM**

15-049

### **Development of Mine Haul Road Surfacing Condition Monitoring Through Digital Image Processing**

*R. Thompson<sup>1</sup>, S. Hahn<sup>2</sup> and S. Pastor<sup>3</sup>; <sup>1</sup>Department of Mining Engineering, Curtin University WASM, Kalgoorlie, WA, Australia; <sup>2</sup>Former student: Dept Mining Engineering, Curtin University WASM, Kalgoorlie, WA, Australia and <sup>3</sup>Current student: Dept Mining Engineering, Curtin University WASM, Kalgoorlie, WA, Australia*

As the concept of autonomous haulage systems (AHS) moves from proto-types to production-ready applications, the operating performance of the haul road will become 'mission critical' to the overall success of AHS. Deterioration in road performance will require remediation, human intervention and significant, albeit temporary, changes to operating procedures, to accommodate road maintenance. With autonomous trucks comes the opportunity to increase haulage efficiencies and reduce costs, but only if the design of the road, and it's associated deterioration rate, is predictable and manageable. This paper presents the development of a digital photogrammetric approach to characterising a mine haul road surfacing. Currently, the approach is based on physical particle size distribution (PSD) assessments of 'in-road' material. Digital imaging approaches to PSD assessed here use digital analysis software tools, together with in-service haul road images which are assessed to determine the applicability and reliability of the approach to deliver a real-time assessment of haul road surfacing conditions and thus to identify the road maintenance interventions required to address deterioration.

**3:05 PM**

15-068

### **Redefining the Ultimate Pit: Improving NPV by Factoring Scheduling into Design**

*H. Burton; Dassault Systèmes Canada Software Inc., Vancouver, BC, Canada*

The selection of the ultimate pit shell has a major impact on the overall value of a mining project. The size and shape of this pit drives the selection of pushbacks, equipment, and project strategy, each of which are significant drivers in their own right. Optimisation of the ultimate pit shape is typically done using the Lerchs-Grossman algorithm with inputs of production costs, commodity prices, and pit slope constraints. This method ensures that every tonne mined is profitable but does not take into consideration the timing of material release. This timing is essential when calculating the Net Present Value (NPV) of the project, which is one of the most popular metrics for valuing deposits. Often, when the mining schedule and discounting are

applied, material that would have been profitable before discounting becomes sterilized. The objective of this paper is to show the methodology for improving ultimate pit selection by considering the production schedule. Application of this technique will generally produce a smaller and higher-value pit than using the Lerchs-Grossman algorithm alone.

**3:25 PM**

### **The Spatial Aspect of the Long-Term Open Pit Mine Sequence Optimization**

*R. Halatchev; Private, RH Mining Consultancy, Brisbane, QLD, Australia*

The mine sequence optimization in open pit mining is a procedure that predetermines the efficiency of the production scheduling optimization. From a technological point of view the mine sequence optimization deals with two aspects – spatial and time. Each of them plays a tremendously important role in searching for the optimum solution of the open pit design problem. The paper treats the spatial aspect of the mine sequence optimization, which is revealed in the context of determination of the optimum number of cutbacks of an open pit mine. A mathematical solution of this problem has been developed with the utilization of a combinatorial analysis. The solution is based on a multi-variant investigation of the optimum mine sequence with the implementation of an author's method for production scheduling optimization, which uses the Net Present Value as a criterion for assessing the economic efficiency of mine sequencing. A case study is provided to illustrate the applicability of the approach. The results obtained reveal the complex nature of the variation of the Net Present Value as a function of the cutbacks geometry.

## **Mining & Exploration: Operations: Underground Mining: Challenges of Today**

**2:00 PM • Tuesday, February 17 • 707**

*Chair: T. White, AMEC, Denver, CO*

**2:00 PM**

### **Introductions**

**2:05 PM**

### **Twin Metals Minnesota Maturi Project - Challenges Associated to Project Ramp-Up**

*B. Syers; Project Development, Twin Metals Minnesota, Saint Paul, MN*

The TMM Project is located in the Duluth Complex in NE Minnesota on the Iron Range and targets extraction of Copper, Nickel, and PGM elements. Key components include an underground mine operating at 50,000 tons per day, a concentrator producing copper and nickel concentrates, a tailings storage facility and paste backfill plants. A pre-feasibility study has been

recently completed. The focus for this presentation is on challenges associated with ramp up of large underground mining operations and their relevance to the TMM Project. The ability to achieve rapid mine and mill ramp-ups, while ensuring product quality standards, can represent a major challenge. The ideal scenario is for the processing facility and mine to match throughput rates at full capacity as soon as possible. To commence and sustain production, often complex infrastructure must first be developed, presenting a significant schedule risk. For the TMM Project every effort has been made to eliminate unnecessary complexity with the mine design, mining methods, and ore handling allowing efficient management of resources. This has been coupled with the application of robust technology solutions.

**2:25 PM**

### **Making Old Mines New**

*M. Schroeder; Nyrstar, Gordonsville, TN*

Nyrstar is an integrated mining and metals business with market leading positions in zinc and lead, and growing positions in other base and precious metals; essential resources that are fuelling the rapid urbanization and industrialization of our changing world. Nyrstar has mining, smelting and other operations located in Europe, the Americas, China and Australia. In 2010, Nyrstar reopened six historic zinc properties in Tennessee. One mill and three mines are located near Nashville, TN; with a second mill and three mines approximately 150 miles east near Knoxville, TN. When reopening old mine complexes, the first few years are spent learning the intricacies of mines, fine tuning the mills and establishing an effective workforce. Upon conquering the learning curve, there is a need to step back and reevaluate the direction and strategy based on current realities and upcoming endeavors. In 2013, Nyrstar made personnel available to focus on the evaluation process. This presentation discusses the process of re-envisioning the future now underway at Nyrstar Tennessee mines.

**2:45 PM**

### **Technical and operational Aspects of Autonomous LHD Application in Metal Mines**

*J. Paraszczak<sup>1</sup>, A. Gustafson<sup>2</sup> and H. Schunnesson<sup>2</sup>; <sup>1</sup>Mining, Metall., Mat. Engrg, Université Laval, Quebec City, QC, Canada and <sup>2</sup>Division of Mining and Geotechnical Engineering, Lulea University of Technology, Lulea, Sweden*

Due to safety concerns, automation of load-haul-dump (LHD) machines receives more and more attention from mine operators. However, although there are currently three such systems commercially available, relatively few mines opt for their application. This paper looks into the issues related to the implementation and successful use of autonomous LHDs. It reviews the needs for dedicated infrastructure, safety measures and precautions to be taken, preferable mine layouts, etc. Some info from the existing systems or those used in the past will be given to expose the problems encountered in practice. The paper will look also into operational issues (reliability, maintainability, utilization, production rate, etc.), as compared to conventional manually operated machines. The paper will look also at questions of operational flexibility of automated systems: versatility in changing mine conditions, vulnerability to mine related prob-

lems, moving the systems to another location, etc. Conclusions will be focused mostly on the aspects requiring attention at the stages of prefeasibility or feasibility studies in order to maximize the chances that autonomous loading system will become a success.

**3:05 PM**

### **Installation of an Alimak Elevator System for a Mine Escape-Way at the Eagle Mine in Michigan**

*J. Larsen; Cementation, USA, Salt Lake City, UT*

All U.S. underground mines are required under MSHA to have a mechanical means of secondary egress if the mine egress is greater than 300' vertical feet. The former owner of the Eagle Mine, Rio Tinto PLC, contracted Cementation USA to raise bore two 14'9" diameter raises for intake and exhaust ventilation, and to install a an Alimak Elevator System, to complete the emergency egress raise. This presentation reviews the project from boring of the vent raises through the ground support and elevator system hardware installation and final commissioning.

**3:25 PM**

### **Challenges with an Underground Paste Plant from Supply to Strength - Kensington Mine - Coeur Alaska**

*T. Haller and T. Haller; Mine, Kensington Coeur Alaska, Juneau, AK*

The Kensington Mine in southeast Alaska operates an underground paste plant that has proven to be successful from construction, commissioning, and into full operation. Cement as binder has been replaced by a ninety percent slag/ten percent cement (90/10) binder. The percentage of overall binder in the paste fill has been reduced and pumping pressures have dropped. The 90/10 slag/cement paste fill has been placed in primary stopes. Mining secondary stopes between the 90/10 Slag paste filled stopes is the final chapter.

**3:45 PM**

### **Development Challenges at Resolution Copper, Superior, Arizona**

*C. Pascoe; Resolution Copper, Superior, AZ*

The Resolution Copper Project is a large, deep seated Copper porphyry deposit that is located approximately 110km southwest of Phoenix AZ. The currently plan is to develop a high tonnage panel caving operation at more than 2km below the surface that will be accessed by a number of large, high capacity shafts. The project is currently in the study phase with ongoing construction of a shaft and other underground workings. There are a number of technical challenges that have been identified and experienced to date with the project particularly related to the depth including high virgin rock temperatures (80 degrees C), unexpected water inflows and a relatively weak rock mass. This presentation will present our experiences and challenges to date in developing this world class copper resource.

**4:05 PM****Understanding the influence of Geological Structures – an often overlooked important aspect in the stability of Operating Mines***G. More O’Ferrall; Independent Consultant, North Vancouver, BC, Canada*

In the mid-1990s a large fall of ground occurred on Lonmin’s Eastern Platinum Limited’s 2 Shaft. The source of instability was attributed to mining faces approaching a dyke. Spalling along the top corner of a 15-metre wide crown pillar was reported at a depth of approximately 220 metres below surface on EPL’s 3 Shaft during 2003. The back areas on the level above the crown pillar revealed that a large-scale FOG spanning several raiselines had occurred. An investigation was conducted to determine the cause thereof. Panel spans were reduced thereby resulting in an increase in pillar width. Cementitious grout packs were also introduced to supplement the prestressed timber elongate support units. The combination of these two remedial actions stabilised the working stopes, and provided an opportunity to study potential mechanisms behind the instability of the worked-out stopes. The reader is introduced to the prevailing ground conditions, support design and mining practices at the time of the collapse. The reasoning behind the investigation process and results thereof are discussed and theories around the basic cause of the collapse are proposed.

**Mining & Exploration: Technology:  
Mine Discrete System Simulation****2:00 PM • Tuesday, February 17 • 703***Chairs: K. Hindle<sup>1</sup>, Hatch, Mississauga, ON  
E. Tarshizi<sup>2</sup>, University of Nevada, Reno, Reno, NV***2:00 PM****Introductions****2:05 PM****Proving that Simulation can be a Powerful Tool in Mine Planning and Decision-making***M. Franklin; MOSIMTEC, LLC, Herndon, VA*

The goal of this paper is to prove to key decision makers that simulation can be a powerful tool in mine planning and decision-making. A mining transport simulation model is constructed to represent the current operation of a shovel and truck transport process. Some key features included in the discrete system simulation of the truck and shovel operation include Rimpull curve interpolation for truck travel speeds, shovel swing, GIS coordinates for haul routes, and various raw material characteristics. This paper provides more detail regarding approach, input parameters, model development, level of abstraction, metrics, and output analysis. Ultimately the model output is validated with actual historical data from the operating mine, to

prove accuracy and value of simulation. The value of visualization and animation through dynamic simulation modeling is also discussed.

**2:25 PM**

### **Simulation and Animation of Marigold Mine with Dynamic Pit Operation**

*E. Tarshizi<sup>1</sup>, T. Rice<sup>2</sup>, V. Ibarra<sup>1</sup>, J. Sturgul<sup>3</sup> and D. Taylor<sup>1</sup>;  
<sup>1</sup>Mining & Metallurgical Engineering, University of Nevada, Reno, Reno, NV; <sup>2</sup>Technical Services, Silver Standard Resources, Inc., Winnemucca, NV and <sup>3</sup>School of Civil, Environmental, Mining Engineering, The University of Adelaide, Adelaide, SA, Australia*

The Marigold mine has been in operation for the last twenty-five years. It is a surface gold mine located east of Winnemucca, Nevada in Humboldt County and encompasses approximately 28.9 mi<sup>2</sup>. Marigold was originally owned by Rayrock, followed by Glamis, then Goldcorp and Barrick Gold Corporation but recently was purchased by Silver Standard Resources Inc. on April 4, 2014. This truck-shovel operation consists of many open pits and waste dumps, and uses run of mine heap leaching to extract gold from the ore. This project is being conducted to design and develop a haulage simulation and animation model of the existing mine operation, calibrate and validate the model, and carry out different “what if?” scenarios for mine planning and optimization. The simulation software used for modeling Marigold is GPSS/H®, and Proof Professional® is used for the animation. Mine simulation is a beneficial tool that can assist mining operations to run different scenarios before implementing in real life.

**2:45 PM**

### **Discrete Event Simulation of the Open Pit Mining Operation Using ARENA and Cost Effective Monitoring Instrumentation, a Case Study**

*J. Sattarvand; Mining Engineering, Sahand University of Tech., Tabriz, Iran (the Islamic Republic of)*

Current status of mining operation in a copper open pit mine has been simulated in ARENA simulation environment in order to search for the productivity optimizations. Study has been started by data collection which has been accomplished by means of installation of a series of GNSS/GSM units on mining trucks. Then a global tracking system interface designed and generated data has been collected in a database and visualized with a web based application. Collected data has been used for determination of the distribution functions related to the truck cycle times, loading, dumping and maneuver times. Simulation models have been constructed in the next step and validated by entering input data and comparison of the model outputs with real run of mine. Analysis showed that a huge potential of improvement exists through modifications in the fleet. Performance of the modified operation could be upgraded by application of the dispatching systems. Several models have been built for different attitudes of dispatching and various sce-

narios of dispatching were tested. It was showed that 7 percent of extra production could be generated by installation of mine monitoring and dispatching system.

**3:05 PM**

### **Mine Simulation and Short Term Planning**

*C. Stout<sup>1</sup> and P. Conrad<sup>2</sup>; <sup>1</sup>Cortez Hills Open Pit Mine, Barrick Gold Corporation, Elko, NV and <sup>2</sup>Mining Engineering, Montana Tech, Butte, MT*

Often in mine planning it is assumed that shovels advance at specific tonnage rates with no dependency on cycle times or impact to/from other shovels. A short range planner may adjust the planned production from each shovel based on experience or as a percentage of a forecast value. While such techniques may present a quick or "close enough" solution, the short range planner may be over estimating some portions of the operation while underestimating other portions. Such estimates lead to emphasizing drilling in the wrong locations, potentially delaying assay turnarounds, and ultimately parking a shovel. Having the entire system modeled becomes crucial when mining no longer follows the normal flow. This study developed a computer model for short-range and mid-range planning using GPSS/H.

**3:25 PM**

### **The Advantages of Using Discrete Event Simulation to Estimate Mine Haulage Requirements**

*O. Wyberneit<sup>1</sup> and A. Price<sup>2</sup>; <sup>1</sup>Technology, RungePincockMinarco, Lakewood, CO and <sup>2</sup>Technology, RungePincockMinarco, Brisbane, QLD, Australia*

This paper will examine how discrete event simulation can be used to model mine haulage systems. A number of mining operations around the world are using simulation models as an integral part of their mine planning process. When used across multiple planning horizons (short and long term), the models have become a very powerful tool for reality checking of schedules and performing what-if analysis. Operational expertise is essential for model calibration. Models need to be sophisticated yet have easy to understand reports in order to support the decision making process.

**3:45 PM**

### **Development of a Context-Based Simulator with Self-Generated Scenarios of Large-Scale Production Mines**

*V. Tenorio and S. Dessureault; Mining and Geological Engineering, University of Arizona, Tucson, AZ*

Keeping high productivity in large-scale mines poses a complex task that requires special controlling and monitoring tools for displaying key information to help supervisors make the right decisions in order to achieve planned production and quality goals. Simulation models have traditionally been used at a high level for long-term decisions. However, at a tactical level, where

decisions need to be modeled in the current shift, details and subtle changes can make significant differences. A near-real-time data warehouse is used to absorb and integrate data from multiple systems into a single context through a minimal delay. An auto-generating simulation system that uses current or past details was created for decision support. Its development began with a systems analysis wherein the key modeling units, such as location, conveyors, truck cycles, and other variables were organized into object-information/process pairs that could be replicated and connected. The core challenges in design and execution of such a system are further explored. The uniqueness of this feature helped to expand the capabilities of the simulator for analyzing multiple operating scenarios.

**4:05 PM**

15-033

### **Results of Discrete Event Simulation in a Large Open Pit Mine**

*S. Dindarloo<sup>1</sup> and M. Osanloo<sup>2</sup>; <sup>1</sup>Mining and Nuclear engineering, Missouri University of Science and Technology, Rolla, MO and <sup>2</sup>Mining and Metallurgical engineering, Amirkabir University of Technology, Tehran, Iran (the Islamic Republic of*

Abstract Truck-shovel systems are the dominant material loading and haulage machinery in open pit mining operations. Optimal selection, sizing, and allocation of this capital intensive equipment is highly desirable for both achieving production targets and improving the mine's economics. In this study, discrete event simulation technique was applied for modeling material transportation in Golegozar open pit iron ore mine in Iran. Direct observation of the material loading and haulage for duration of three months resulted in statistical modeling of the operation in the form of probability distribution functions. These probability models were used as the inputs of a stochastic simulation model constructed in GPSS/H simulation language. The model was validated through comparison with the actual operation and was used to test different what-if scenarios and sensitivity analysis of the current system. Some modifications in the number of trucks, shovels, and dispatching strategies were proposed. Simulation resulted in considerable improvements in the mine's production and economics. Keywords: Truck-shovel operation; discrete event simulation; equipment selection; open pit mining.

### **Mining & Exploration: Technology: Technology Innovations in Mine Production Systems**

**2:00 PM • Tuesday, February 17 • 704**

*Chairs: L. Clark<sup>1</sup>, Independent Consultant, Golden, CO  
M. Bartlett<sup>2</sup>, Desert Falcon Consulting, Tucson, AZ*

**2:00 PM**

### **Introductions**

**2:05 PM**

15-014

## **Providing Value Through Automation in the Mineral Processing Industry**

*R. Cook<sup>1</sup> and F. Mielli<sup>2</sup>; <sup>1</sup>Schneider Electric, Foxboro, MA and <sup>2</sup>Schneider Electric, Alpharetta, GA*

Mineral deposits require substantial amounts of energy to transport and process into useable form, and as such present a real processing challenge in that the deposits are never homogeneous and ore body compositional characteristics are all over the map! Extracting the desired mineral(s) from the deposit at sufficient profit margin, despite severe fluctuations in market price, requires process automation architecture capable of supporting an integrated enterprise solution. Such an operation encompasses the activities of individuals, process units, process areas, plant level activities, mine management and business planning and accounting systems. Key to the automation process is the aspect of value generation. This paper brings together the various requirements for the automation of a mining enterprise and presents the different aspects of how to obtain value across the entire mining operation

**2:25 PM**

## **Monitoring the Most Critical Part of the Mining Process — the face — in Underground Cut and Fill Mines**

*A. Cervinka, S. Cantin and S. Croteau; Newtrax Technologies Inc., Montreal, QC, Canada*

Fresnillo PLC, a mining company which has deployed Newtrax electronic safety and automation solutions at several of its underground mines in Mexico, uses MineHop battery-powered wireless breadcrumb networks to provide real-time data communications at the face in its cut-and-fill operations, with backhaul to surface over fiber (when available) or standard 25kHz VHF leaky feeder channels. With absolutely no cables connecting the MineHop wireless nodes (none for power or signal), the miners install the MineHop nodes themselves in the workplace using only a tie wrap to enable a network that provides sufficient bandwidth all applications. Operationally, most mines have 20+ active stopes in operation at any time producing gold and silver and need to move production to different areas on a moment's notice to satisfy elements like head feed grade requirements for either of the two commodities. The key feature of MineHop which enables Fresnillo to keep workers and mobile equipment online throughout the stoping process is simplicity: 100% of their staff, including operators, can install the network. The maintenance process does not rely on electricians, Radio Frequency or IT professionals.

**2:45 PM****Technology-Assisted Truck-Shovel Spotting: Challenges and Opportunities***J. Brown; Jaybridge Robotics, Cambridge, MA*

In open pit mining, spotting is the process of aligning a truck with a shovel for loading. It is a primary source of inefficiency in the load-haul-dump cycle. Manual spotting varies with operator capability, and often a shovel may wait (hang) while a truck gets into position. Spotting while a shovel works puts the truck at greater risk being struck by the shovel leading to damage, injury, or death. Using technology to assist drivers in spotting could increase efficiency, decrease variability, and reduce the risk of collisions. Reducing average spotting time by a few seconds can generate significant additional revenues or save significantly on operational costs. Any solution must address several challenges in order to be effective. These include determining the relative positions of the shovel and truck; planning the truck's path, especially when a straight line is not sufficient; ensuring that the path does not intersect hazards such as berms; and providing an interface that enables the driver to follow the path accurately. We will discuss these challenges and opportunities, and explore how assisted spotting solutions from Jaybridge Robotics and others are addressing them.

**3:05 PM****Data Driven Production Performance Measurement for Shovels and Draglines***M. Kahraman<sup>2</sup> and S. Dessureault<sup>1</sup>; <sup>1</sup>MGE, The University of Arizona, Tucson, AZ and <sup>2</sup>MISOM Technologies Inc., Tucson, AZ*

Every mine operation strives to get the most from their assets, particularly from their key loading units or material movers, such as shovels and draglines. High precision monitoring systems are important tools to monitor the effectiveness of operators and grade control. These systems can track production, time usage, equipment health and consumables. All this operational data is stored; however, in most cases, the users and managers access this data by only through OEM reports and HMI (human machine interface) screens. However, reports are typically aggregated data, not suitable for in-depth analysis. Managing and analyzing all data generated by these machines can be challenging. Operational data warehouses can centralize data from multiple on-board monitoring systems along with other sources and provide near-unlimited analysis opportunities. However, to motivate analysis, one must engender a culture of regular quantitative introspection. This paper discusses a case study of performance improvement made by draglines and shovels at a large mine operation using scorecards to motivate a culture of analysis, and ad-hoc business intelligence to facilitate analysis.

**3:25 PM****The Off and Now on Again Case for Using Broadband Over Power Lines in Underground Mining***C. Brackpool; Mining Engineering, Colorado School of Mines, Golden, CO*

Given the increase in data requirements and desire for more robust safety communications in sub-surface mining, power line communications (aka PLC or BPL) is getting another look. For a decade several vendors explored injecting signals over distribution feeders. However, attenuation problems and interference from VFD motors, un-shielded cable, and transformers stalled development projects. A new group of non-mining BPL technologists have entered the industry to resolve issues and apply expertise in developing scale-able mesh networks leveraging existing power cabling assets. This compliments or is a replacement for fiber, wireless/radio, and Ethernet. The critical requirement to re-purposing any proven utility grid telecom access infrastructure, into an underground natural resource extraction and processing, is an ability for repetition between BPL concentrators and their subordinate network and routing devices. We will compare the prior mining industry efforts with this renewed activity. The forward look, is anticipation of a growing sensing revolution that saturates IT networks with vast numbers of data point and aggregation nodes.

**3:45 PM**

15-051

**Simulation and Optimization in Open Pit Mines***S. Upadhyay, H. Askari-Nasab, M. Tabesh and M. Mahdi Badiozamani; Civil and Environmental Engineering, School of Mining and Petroleum Engineering, University Of Alberta, Edmonton, AB, Canada*

Increasing demand and market economics have pushed the mining industry to adopt improved mining practices and minimize losses. Simulation, in this regard, has proved to be an efficient tool to help in decision making purposes. We present the development of a discrete event simulation model for a large-scale open pit mine to run experimental scenarios for near optimal decision making. A Mixed Integer Linear Goal Programming (MILGP) optimization model is also presented for shovel allocation optimization. The mathematical model will be coupled with the simulation model at the dispatching stage for shovel allocation optimization and thus it will act as the link to optimal short-term schedule to assist in achieving better mine plan compliance across short-term and operational planning time horizons. The main contribution of this work so far is the development of the MILGP model and development, implementation and verification of the simulation model on a large scale oil sands open pit mine case study. The results obtained so far are promising and the distributions conform to the historical data of the mine proving the applicability of the model for experimental scenario analysis.

## **Optimization of Mining Complexes and Mineral Value Chains**

**2:00 PM • Tuesday, February 17 • 109**

*Chairs: K. Dagdelen, Colorado School of Mines, Golden, CO  
R. Dimitrakopoulos, COSMO Lab, McGill University,  
Montreal, QC*

**2:00 PM**

### **Introductions**

**2:05 PM**

### **Optimising a Mineral Supply Chain under Uncertainty with Long-term Sales Contracts**

*J. Zhang; COSMO - Stochastic Mine Planning Lab, McGill  
University, Montreal, QC, Canada*

A two-stage stochastic mixed integer non-linear program is formulated for a mining complex to optimize strategic and tactical plans. The objective is to find the near optimal decisions for a mineral supply chain in the context with uncertainties in both ore supply and the commodity market (price and demand). The endogenous spot price in the commodity market and long-term sales contracts are considered in the formulation of the mining complex's optimization model and an ad hoc heuristic is developed to deal with the throughput- and head-grade-dependent recovery rate in processing plants. Numerical results indicate that the proposed heuristic is effective and efficient in numerical tests. Based on the proposed model and heuristic, a long-term contract design strategy is proposed for making decisions on the contract price and strategic investments. A shadow price based method is also proposed to evaluate the existing mining schedule.

**2:20 PM**

### **Stochastic Optimisation of Mineral Value Chains – Developments and Applications for the Global Optimisation of Mining Complexes with Uncertainty**

*R. Goodfellow and R. Dimitrakopoulos; COSMO - Stochastic  
Mine Planning Laboratory, McGill University, Montreal, QC,  
Canada*

Major objective when optimising a mining complex is to maximise its value for the primary stakeholders. To achieve this objective, it is necessary to holistically optimise all aspects of the mining complex, including decisions of when to extract materials from the available sources, how to blend or stockpile these materials, and how to best use the available processing streams to satisfy customer demand. This paper presents a new method for the global optimisation of open pit mining complexes with geological uncertainty. The proposed generalised methodology is capable of modelling and holistically optimising mining complexes, including aspects related to production scheduling, blending, stockpiling and non-linear interactions that often

occur in practice, but are over-simplified in existing models. Two case studies are discussed to highlight the need for these complex, stochastic optimisers. Case studies highlight the (a) need to integrate geological uncertainty into the optimization in order to ensure product quality constraints are respected; (b) added value when simultaneously optimising the production schedule and the stockpiling and treatment of extracted materials.

**2:35 PM**

15-053

### **Strategic Mine Planning at Newmont's Twin Creeks Operation**

*K. Kawahata, P. Schumacher and M. Fein; Newmont Engineering, Newmont USA Limited, Golconda, NV*

Newmont's Twin Creeks Operation, part of Nevada operations, produces gold from two large open pit mines. Mined ore is processed at one of three on-site facilities; a refractory mill with autoclaving, an oxide mill and heap leaching facilities. Twin Creeks also processes various off-site sourced concentrates and ore including high grade underground ore from the Turquoise Ridge joint venture with Barrick Gold Corporation. This paper discusses Twin Creeks' strategic mine planning process which is part of in-depth continuous improvement program called 'Full Potential'. The process involves cost analysis, phase design validations, life-of-mine production scheduling optimization, mill blending strategy and stockpile management. Through this full potential strategic planning, Twin Creeks Operation is creating significant values by increasing near term free cash flow and life of mine NPV and achieving cost reductions.

**2:50 PM**

### **Advancing the Accuracy of Uncertainty Models through High-Order Conditioning**

*M. Godoy and C. Meagher; Newmont Mining Corporation, Greenwood Village, CO*

Investment decisions in mining invariably require an assessment of confidence related to the underlying mineral resource estimates. Mining companies address this by requiring projects to adhere to standardized resource confidence profiles at different project development phases, by considering a distribution of Measured, Indicated and Inferred Resources through the production plan. Unfortunately resource categories are defined on the basis of drill spacing without considering appropriate measures of uncertainty related to estimates. Accounting for uncertainty requires its accurate quantification. The current industry practice to characterize geological uncertainty consists of generating multiple realizations of the deposit that honor the data at their location and reproduce first and second order data statistics. This paper presents a case study developed with a mined out deposit showing that the ability to account for high order statistics can improve the accuracy of uncertainty assessment and therefore render models that can better support investment decisions. Results also highlight the shortcomings of using traditional resource classification to support investment decisions.

**3:05 PM****Categorical Simulations for Mine Risk Assessment – Case Studies***A. Jewbali, R. Perry, L. Allen and R. Inglis; Newmont Mining Corporation, Greenwood Village, CO*

The use of conditional simulation to characterize mine plan uncertainty is gaining more use for assessment of risk in mining projects. While the development of grade uncertainty profiles is relatively straightforward and can be validated using standard geostatistical techniques, the addition of geological uncertainty to evaluate total risk remains problematic. Some of the problems associated with geological uncertainty methods include the clustering of data in favourable geologic units, difficulty in training image definition, and the inability to address change of support issues for categorical variables. Despite these obstacles the importance of geological uncertainty as a contributor to total uncertainty has prompted Newmont to explore and evaluate the use of various techniques, including multiple point statistics, on different deposit types.

**3:20 PM****Optimizing the Mining Value Chain under Supply Uncertainty***L. Montiel Petro; COSMO - Stochastic Mine Planning Lab, McGill University, Montreal, CO*

Optimizing mining value chains is founded upon simultaneously optimizing its different components, including multiple deposits, stockpiles, processing destinations and transportations systems, all of which interrelate to affect decisions taken. Mineral deposits are sources of ore from where multiple metallurgical ore types are extracted. Stockpiles contain potential ore, contribute to the blending and act as backup material supply. Raw materials are transformed in processing destinations where multiple operating modes may be available. The products generated from the processing destinations are transported to final stocks/ports. This paper presents a method to generate mining, blending, processing and transportation plans while accounting for supply uncertainty. Given the large optimization problem derived from the flexibility at the different components of the value chain, a solution approach that uses metaheuristics is presented. Implementations of the method show its ability to reduce deviations from capacity and blending targets while improving the expected NPV, which highlights the importance of stochastic optimizers given their ability to generate more value with less risk.

**3:35 PM**

## **Open Pit to Underground: Determining Crown Pillar Location Through NPV Optimization of Global Open Pit and Underground Production Schedules**

*K. Dagdelen<sup>1</sup> and I. Traore<sup>2</sup>; <sup>1</sup>Mining Engineering Department, Colorado School of Mines, Golden, CO and <sup>2</sup>Mining Engineering Department, Colorado School of Mines, Golden, CO*

Many Projects are being planned in the United States, Africa and South America with multiple open pits and some having underground extensions. The determination of location of the crown pillar where a deposit may be mined by both open pit and underground is critical to obtaining maximum NPV for a complex project. This decision is a function of mine and mill capacities, grade tonnage distributions, metallurgical recoveries and related mining as well as processing operating costs. This paper will present a NPV maximizing method for determining crown pillar location using combined global production scheduling optimization of open pits and the underground operation.

## **Research: NORA Safety and Health Research for Small Mines**

**2:00 PM • Tuesday, February 17 • 507**

*Chair: L. Saperstein, Missouri University of Science and Technology, Nantucket, MA*

**2:00 PM**

## **Introductions**

**2:05 PM**

15-104

## **Development of a Prototype Mine Dust Sampling Device for use in Underground Coal Mines**

*B. Goertz, K. Bakhsh, J. Brune, S. McDaniel and T. Rockley; Mining Engineering, Colorado School of Mines, Golden, CO*

Researchers at the Colorado School of Mines have developed a working prototype of a mine dust sample collection device designed to be used with a Coal Dust Explosibility Meter (CDEM). When used in conjunction with the CDEM, the device will be able to provide near instantaneous results on the quality of rock dusting in a tested location. To achieve this, the device provide a pulse of air to a testing surface and collect a sample of mine dust that will be representative of that entrained by a methane explosion. The use of both physical testing and Computational Fluid Dynamic (CFD) modeling have allowed researchers to refine the design to accurately represent the particle entrainment and optimize the sample collection size for the CDEM. The goal

of this prototype will be to verify the versatility of the sampling configurations and understand the limitations of a final product design.

**2:25 PM**

### **Comparison of Diesel and Biodiesel Airborne Exhaust Exposures in an Underground Mine**

*E. Lutz, R. Reed, V. Lee, S. Littau and J. Burgess; College of Public Health, The University of Arizona, Tucson, AZ*

Diesel (D) fuel is widely used in mining, despite being a human carcinogen. Biodiesel (BD) offers potentially reduced exhaust exposures. Using a LHD underground, exposures from D and a 75% BD/25% D (B75) fuels emissions were compared. Monitoring for total and respirable diesel particulate matter (tDPM and rDPM, respectively), total and respirable elemental and organic carbon (tEC, rEC, tOC, rOC, respectively), as well as carbon monoxide (CO), nitric oxide (NO), nitrogen dioxide (NO<sub>2</sub>), formaldehyde, acetaldehyde, naphthalene was performed. Results found that tDPM was significantly higher for B75 than D ( $p < 0.001$ ), while rDPM was lower for B75 than D ( $p < 0.05$ ). Further, tEC, rOC, and NO<sub>2</sub> were lower for B75 ( $p < 0.001$ ,  $p > 0.05$ , respectively), and rEC and tOC was higher ( $p < 0.001$ ). CO, formaldehyde, acetaldehyde, and naphthalene did not differ between fuels, while NO was produced in significantly greater quantities by B75 than D ( $p < 0.05$ ). B75 may reduce rDPM production supporting increased regulatory compliance; however, greater production of tDPM and NO, with similar emission of aldehydes and naphthalene, brings to question if B75 use leads to lesser exhaust-related health risk.

**2:45 PM**

### **Broad Associations between MSHA Regulatory Compliance Measures and Injury Outcomes from 1983-2012**

*R. Reed and E. Lutz; Mining Safety and Health Program, University of Arizona, Tucson, AZ*

This pilot work analyzed basic associations between annual MSHA regulatory compliance- and injury-related data from 1983-2012 obtained from the online msha.gov injury and U.S. Department of Labor's enforcement databases. Operator and contractor injury data were combined, and data for office workers were included. Seven compliance 'inputs' were utilized, ranging from citations (excluding SNS [CT]) and SNS citations (SCT), to inspection hours and penalty amounts. Eight injury 'outcomes' were considered, ranging from fatal to no days lost injuries. Correlation coefficients were determined using a Spearman's rank correlation for the entire period and by decade. In most cases, CT were positively, significantly ( $p < 0.05$ ) correlated with multiple injury outcomes during the 1st decade, negatively ( $p < 0.05$ ) correlated during the 2nd, with no correlation during the 3rd. Generally, SCT were positively ( $p < 0.05$ ) correlated during the 1st and 2nd decades, with virtually no correlation for the 3rd. Other measures will be discussed. This work sheds light on the broad relationships between regulatory compliance and injury outcomes.

**3:05 PM****Small Independent Mines (SIMs) in the U.S.:  
A Hyper-Risk Population?***T. Hethmon; Mining Engineering, University of Utah, Salt Lake City, UT*

The highest rate of injury or death within the industry occurs among the nation's 5,000+ small mines. In the period from 2000 to 2002, fatal injuries occurred two and one-half times as often as in larger mines. Today, the fatality rate in small mines is double the rate in larger mines. Little research has been conducted in the U.S. to understand the underlying factors that make small mines susceptible to these tragic events. What research has been conducted has focused heavily on small coal mines, while the risk is spread across the commodity spectrum. This research focused primarily on the relationship between mine regulatory compliance and resulting occupational injury and illness rates. This presentation will provide a frame of reference for the discussion on small mine safety by summarizing the available literature, describing the cohort of mines at risk with emphasis on small independent mines (SIMs) and variables associated with increased sector mortality, highlight a new NIOSH research program aimed at small mine safety interventions, and offer two broad interventions designed to help address this hyper-risk population of mines.

**3:25 PM****Trends in Heat Stress Incidents, 1984-2013***J. Weeks; Metal and NonMetal Mine Safety and Health, Mine Safety and Health Administration, Arlington, VA*

Incidents of heat stress among metal and non-metal miners were identified in Part 50. MSHA has no regulation for heat stress. Incidents were converted to annual incident rates, analyzed for trends and were classified by surface v. underground mines, by SIC code, by month, and by state. There were a total of 875 non-fatal events. There was significant variation in rates between years with a slight increase over the time period. Incidents were more common at surface than underground mines and showed a strong seasonal trend for surface mines, they were more common in southern states, absent in some northern states, and common at mines with hot processes. Unconsciousness and calling an ambulance, suggesting a serious event, was reported in about a quarter of these events. Neither the TLV for heat stress, the WBGT, nor heat stress prevention programs were mentioned. A major factor in causing and preventing heat stress is manual labor. Other causes include direct sunlight, hot processes such as at cement plants and aluminum processing facilities, and very deep mines.

**3:45 PM****The health of workers in small underground coal mines**

*D. Blackley, C. Halldin and A. Laney; Division of Respiratory Disease Studies, National Institute for Occupational Safety and Health, Morgantown, WV*

Recent evidence has shown that compared to workers in large coal mines, those in small underground mines are at greater risk for coal mine dust lung disease (CMDLD), including pneumoconiosis, COPD and dust-related diffuse fibrosis. Using data from the NIOSH Coal Workers' Health Surveillance Program (CWHSP) we found that after adjusting for miner age and accounting for within-miner correlation, those from small mines (<50 workers) were five times more likely to have evidence of progressive massive fibrosis than those from larger mines. Subsequent analysis of CWHSP data found that in central Appalachia, workers from small mines were also more likely to have abnormal lung function. Earlier reports identified higher rates of transport-related injuries and fatalities in small mines. Hypothesized risk factors for these disparities include differences in coal seam height, mining methods, and workforce experience and training, as well as other factors. Next steps should include systematic identification of factors responsible for high rates of respiratory disease in small mines, as well as an updated synthesis of data describing occupational injury disparities.

**UCA of SME: Energy Pre-Developed Longwall Recovery Room II****2:00 PM • Tuesday, February 17 • 111**

*Chairs: R. Henn, Brierley Associates LLC, Littleton, CO  
D. Klug, David R Klug & Associates Inc, Murray, PA*

**2:00 PM****Introductions****2:00 PM****State of the Art of Blind Bore Shaft Construction**

*N. Zeni; Shaft Drillers International, Mt. Morris, PA*

Shaft Drillers International (SDI), is the parent company of several specialty construction and drilling companies, including the two oldest blind bore shaft construction companies in the world, North American Drillers and Zeni Drilling Company. These two operating companies represent world class leadership in the development of deep, large diameter shafts in rock formations. With more than forty years of experience, SDI has successfully completed more than 20 miles of blind drilled, large diameter shafts. Blind drilling allows shafts to be fully constructed from the surface, eliminating the need for personnel to enter the shaft. Shaft construction is independent of all underground operations. Upon completion, ancillary equipment such as fans or hoists can be installed ahead of the underground operation, which reduces the schedule impacts associated with shaft con-

struction. Blind bore shaft construction is proven in challenging ground conditions with minimal environmental impact. Shafts can be used for mine or other underground development. Other uses for blind bore shafts include; ventilation, underground service, material removal, raw water intake or conduits for utilities.

**2:20 PM****Mechanized Shaft Sinking Applications**

*P. Rennkamp; Herrenknecht, Schwanau, Germany*

Mining companies have to break new ground to further modern, efficient and safe future mining projects. Herrenknecht supports companies on this path with innovative machine technology. During the last past years Herrenknecht has developed a range of shaft sinking applications. One of this is the Extension Shaft Boring Maschine (SBE). The machine has been designed for shaft diameters of 7,5 to 9,5 meters and the application in hard rock condition. The SBE utilizes a conical shaped full face cutterhead. For the application of the SBE a pre-hole is required.

**2:40 PM****Twin Vehicular Box Tunnels, Liberty University**

*A. McGinn; Brierley Associates, East Syracuse, NY*

Liberty University needed access to their growing campus. The solution- Construct two 20.5 foot high, 32 foot wide, 130 foot long cast on-site reinforced concrete box tunnels. Now complete, the tunnels convey four lanes of traffic beneath three active rail lines operated by Norfolk Southern. Although conventional construction of these types of tunnels is by jacking, a novel approach was selected to pull both boxes through the existing railroad embankment via post-tensioned tendons installed through the embankment and walls of the tunnels. This presentation will provide insight on the planning and design aspects associated with building under an existing active rail-line.

**3:00 PM****Laboratory Research on Soil Conditioning for EPB TBM Tunneling**

*Y. Wu; Colorado School of Mines, Golden, CO*

In order to fully investigate the properties of foam conditioned soils in EPB TBM tunneling, a Pressurized Testing Chamber (PTC) has been designed and developed by our group at CSM for evaluating the compressibility, shear strength, and abrasivity of foam conditioned soils. The testing system which includes foam generator, PTC, and tools is introduced in this presentation. In addition, experimental results of compressibility, shear strength, and abrasivity of conditioned soils are presented. The experimental results show that appropriate foam conditioning affects soil properties significantly and it improves the performance of EPB TBM tunneling.

**3:20 PM**

## **Road Tunnel Fire Management Strategies**

*R. Ostoyich and J. Brune; Colorado School of Mines, Golden, CO*

Colorado School of Mines In the United States, road tunnels of substantial length generally have a fire detection and/or mitigation system installed. While these systems are expected to enhance fire safety in the tunnels their key components are often operated individually from one another. Researchers believe there is a need to look at the overall system response to a variety of fire and ventilation scenarios, including ventilation controls and escapeway management, in connection with the fire detection and suppression installations to ensure appropriate incident management. Through computational fluid dynamics (CFD) fire modeling, researchers at the Colorado School of Mines are developing optimized strategies and best practices for response to fire emergencies in different major road tunnels with the goal to protect human life and property.

**3:40 PM**

## **Development of Boulder Impact Detection via TBM Vibration Measurement**

*J. Buckley; Colorado School of Mines, Golden, CO*

This research investigates TBM vibration as an indicator of cutterhead impacts with boulders. An EPB TBM was outfitted with accelerometers to monitor vibration during excavation of the North Link light rail tunnel project (N125) in Seattle, Washington. Accelerometers were placed on and around the bulkhead, the nearest possible placement position where vibration from the cutterhead emanates. Joint time-frequency analysis of vibration response reveals that key frequencies are proportional to operating parameters and impacts produce broadband frequency bands. Further analysis will allow a single variable to be output to the TBM operator in real-time to indicate the likelihood of boulder impact.

## **Valuation II: Case Studies**

**2:00 PM • Tuesday, February 17 • 112**

*Chair: T. Knobloch, AIMA, Marietta, OH*

**2:00 PM**

## **Introductions**

**2:05 PM**

## **Price Versus Value: Was Oscar Wilde Right?**

*A. Stagg; Stagg Resource Consultants, Inc., Cross Lanes, WV*

Oscar Wilde, an Irish playwright, poet, and author, once wrote that “Nowadays people know the price of everything and the value of nothing.” Based on the author’s experience in the min-

eral industry during the course of his career, including a substantial measure of acquisition-related and appraisal involvement, it appears that this aphorism may have relevance to the appraisal industry more than a hundred years later. A synthesis of a number of projects completed during the past several years illustrates the tendency to confuse price with value in a variety of circumstances, including condemnation and takings matters, mineral trespass issues, and financial transactions. Appropriate appraisal techniques that are to be used based on circumstance and venue are discussed and placed in perspective.

**2:23 PM**

### **Tales from the Trenches – Determining Mineral Value**

*T. Keresztes; Behre Dolbear Capital, Behre Dolbear, Plainsboro, NJ*

Tales from the Trenches – Determining Mineral Value. A case study review of in-situ mineral value determination using various methodologies, with emphasis on DCF considerations.

**2:41 PM**

### **A comparison of two early stage valuations of similar industrial mineral projects**

*C. Wyatt; Behre Dolbear, Golden, CO*

A comparison of two initial valuations of similar industrial mineral properties, where the markets are opaque and only initial exploration sampling and product testing has not yet been performed. The comparative review will cover the methods employed with an emphasis on the caveats and the resulting discounting of value.

**2:59 PM**

### **Case History re Actual Mineral Property Sales in Pennsylvania**

*J. Gustavson; Mineral Appraiser LLC, Boulder, CO*

The market for mineral properties in the Marcellus has matured. First, acreage with historic low-royalty and lease bonus, some Held-by-Production, was augmented by a giant land rush with high royalties (16-20%) and bonus in the thousands of dollars/acre. The latter enabled mineral appraisal by the lease bonus approach. This was followed by discoveries of liquid-rich “sweet spots”. Royalty, or rather mineral property buyers finally appeared including long-term individual investors as well as funds, brokers and even syndicators. Examples, some of them crass, will be given. These buyers together with selling landowners now present a dynamic market. The transactions can be researched and adjusted to provide comparable sales of actual mineral property. Ways to arrive at “confidential” sales prices will be shown for Butler County. Many parameters must be included when adjusting these sales prices to appraise undeveloped mineral rights. Examples will be shown. Also, the old rule-of-thumb that Fair Market Value equals a multiple of lease bonus was found still to be valid, albeit adjusted to reflect the resource play nature of this and other shale plays.

**3:17 PM****Mineral Appraisal Lessons***M. albert; DCR, Inc., Denver, CO*

Appraising discussions follow the use of comparable sales vs the income approach involving USPAP and UASFLA content, valid appraisal subjects, methodologies, and preferences in report formatting and scope of work. Results from several past appraisals are noted relative to these issues.

**3:35 PM****Definition of Rights, A Fundamental Step in the Appraisal of Oil and Gas Interests***E. Moritz; Gustavson Associates, LLC, Boulder, CO*

Oil and gas interests can be complex and need to be well understood before conducting an appraisal. Defining the type of interest along with any restrictions or reservations can impact subsequent steps in the appraisal process. This presentation reviews examples of various types of oil and gas interests and how they should be considered as part of the approach to value.

**3:53 PM****Google Earth Pro As Valuation Tool***M. Shumway; Shumway Resources LLC, Worthington, OH*

Google Earth Pro is a valuable tool for the completion of valuation engagements and is a cost-efficient and effective tool for viewing and presenting geospatial data relevant to valuations. Google Earth Pro includes high resolution aerial photos and cultural data for much of the world and in the United States often includes surface parcel ownership data. The Google Earth Pro environment can incorporate many different sources and formats of existing geospatial data including ESRI shapefiles, spreadsheets, and text files with coordinate data. We will demonstrate how we use Google Earth Pro and other tools to streamline our analysis and presentation of geospatial data and we will show examples of our workflow and data compilations for oil and gas valuation engagements.

**4:11 PM****Market Extraction of Income Modeling Parameters in New York and Pennsylvania***Z. Smith; Congdon & Company, Endicott, NY*

This study addresses market extraction of Bonus Multipliers, Discount Rates, and Time-to-Production in the Marcellus Shale play of NY and PA. One case that is studied includes a recent lease offer made to the Kirkwood Coalition in NY State for

11,500 acres, despite the existence of an indefinite moratorium. The primary focus is upon valuation from the perspective of the landowner.

## OPERATOR'S SESSION

**4:00 PM • Tuesday, February 17**

### **Barrick North America's, Operator's Session**

**Room: 601 - 603 • Colorado Convention Center**

*Featuring: **Craig Zablocki,***

***"Be ALL in - Getting To 100%"***

The businesses and organizations that are thriving are able to develop a culture of engagement, creativity and fun. A culture where people are all in. Could your organization use more energy, more engagement, more creativity, more direct and collaborative communication? In this session, be ready to learn, laugh and Be All In - both personally and professionally.

Wednesday, February 18

Morning

## Coal & Energy: Mining Innovations and Improvements

9:00 AM • Wednesday, February 18 • 504

Chairs: *M. Trevits*<sup>1</sup>, South Park, PA

*H. Dougherty*<sup>2</sup>, Virginia Tech, Newport, VA

9:00 AM

### Introductions

9:05 AM

### Characterization of Tensile and Shear Loading on Indented PC-Strand Cable Bolts

*S. Derycke*<sup>2</sup>, *S. Tadolini*<sup>1</sup>, *A. Bhagwat*<sup>1</sup> and *T. Hanselaer*<sup>2</sup>;

<sup>1</sup>Technology, Orica, Georgetown, KY and <sup>2</sup>R & D, NV Bekaert SA, Brussels, Belgium

The tensile and shear strength of intrinsic bolting support systems has always been a major concern of designers. Laboratory testing was completed to evaluate the tensile and shear strength of individual wires and completely wound PC-strand cables. Both smooth wires and the recent anchorage enhancement innovation of indentation were evaluated and compared. The testing protocol detailed in ASTM, utilizes a mandrel system that was investigated for 3 different diameters. The results demonstrate that the difference between smooth and indented wires is negligible and insight into the shearing mechanism and evaluation techniques will be presented.

9:25 AM

15-106

### The Movement of Perfluoromethylcyclohexane (PMCH) as a Tracer Gas through Seal Material Used in Underground Coal Mines

*K. Brashear*, *J. Amante*, *K. Luxbacher* and *N. Ripepi*; Mining and Minerals Engineering, Virginia Tech, Blacksburg, VA

Over recent years, specifically following the MINER Act of 2006, an increasing amount of manufacturers of underground mine seals in the United States have begun using a form of pumpable cement or shotcrete to create barriers separating the working and abandoned sections of underground coal mines. This seal material, while generally considered to be homogenous and solid, contains a network of microcracks, voids, and delaminations. Generally, it has been assumed that methane (CF<sub>4</sub>) leakage around these seals is a result of movement around the boundary interface between the seal and surrounding strata. Using a perfluorinated tracer compound, perfluoromethylcyclohexane (PMCH), the movement of gases can be monitored through seal material to observe how gases move through seal material, both intact and with faulting in the material. This paper

documents two large experiments where the movement of PMCH was monitored in the field, along with modeling confirmation using 3D visualization software.

**9:45 AM**

## **Methane Flow and Concentration Model in a Coal Silo**

*B. Wang; Mining Engineering, University of Nevada, Reno, Reno, NV*

Coal silos are transfer stations on the haulage route starting from the coal mines. The freshly mined coal is loaded by conveyor belt to the silo at the top. The silo is emptied from the bottom to another set of conveyor belts or to transportation trucks. The stored coal gives off native methane contained by absorption in the coal lumps. The residual time of stored coal is of several days in the silo which provides buffer capacity between the variable inflow and efflux of coal depending on the transportation cycles. Methane comes out with the unloaded coal to the silo building where it may reach critical concentration for methane blast. A numerical model is presented for the prediction of methane liberation during coal offloading from the silo in the building enclosure. The model accounts for the methane liberation characteristic of the coal lumps, the diffusion of the methane into the air gaps in the silo, the moving of the coal in the silo, and the flow and concentration of methane into the air in the building during offloading. The results show that under certain conditions critical methane concentrations may be encountered at offloading points of the silo.

**10:05 AM**

## **Development of Moisture Tolerant Rock Dust for Improved Mine Safety**

*D. Anstine; Carbonates, Imerys, Roswell, GA*

In damp or wet underground coal mines current rock dusts cake when wetted and subsequently dried. Concerns arose regarding this caking and its effect on the adequate dispersion of the rock dust with the fugitive coal dust and its ability to abate an explosion. Imerys responded to BAA (Broad Agency Announcement) #2012-N-14257 to investigate technologies that would render rock dusts more moisture tolerant and allow for easier dispersibility under damp or wet conditions. The project was centered upon the development of a rock dust that was more moisture tolerant but still met the existing requirements of 30 CFR 75.2. The developed samples when compared to conventional rock dusts exhibited a significant improvement in dispersibility while demonstrating an equivalent explosion inerting capability. In addition to improved dispersibility and comparable inerting capabilities, the samples evaluated, met the existing requirements of 30 CFR 75.2. A larger sample was evaluated in the Bruceton Experimental Mine. The sample dispersed immediately after application and continues to disperse over time.

10:25 AM

15-007

## Experimental Study on Spontaneous Combustion Characteristics of Repeated Oxidation of Non-caking Coal

Z. Jingyu<sup>1</sup> and D. Jun<sup>2</sup>; <sup>1</sup>*Xi'an University of Science and Technology, Xi'an, China* and <sup>2</sup>*Key Laboratory of Western Mine Exploitation and Hazard Prevention of Ministry of Education, Xi'an, China*

In the process of slicing mining for coal seam groups or thick coal seams, repeated oxidations, due to the effect of mining, may take place for the remaining coal in the gob of the lower seam. So, spontaneous combustion is prone to occur in this area. The study on the oxidation of coal is conducive to the safe mining of the coal seam groups and thick coal seams. The non-caking coal was collected as coal samples. The raw coal sample with primary oxidation and the sample after secondary oxidation and third oxidation were obtained after a certain treatment of the coal. It uses temperature-programmed system, proximate analysis and ultimate analysis as experimental method to compare the releases of gaseous products of spontaneous combustion characteristic parameters of the repeated oxidized coal sample. With the increase of oxidation times, experimental results indicate that the rate of the oxygen consumption, the release rate of carbon monoxide and the intensity of heat release had significant reduction. The characteristic temperature dropped and the size of the pores in coal decreased as well. The specific surface area became larger, causing a larger contacting area with oxygen.

10:45 AM

15-034

## Time Series Analysis of Mining Shovels Failures

S. Dindarloo<sup>1</sup> and E. Siami Irdemoosa<sup>2</sup>; <sup>1</sup>*Mining and Nuclear engineering, Missouri University of Science and Technology, Rolla, MO* and <sup>2</sup>*Geological Engineering, Missouri University of Science and Technology, Rolla, MO*

Cable/hydraulic shovels are the main loading machinery in surface mining operations. Excellent knowledge of reliability, maintainability, and mechanical availability of shovels is a critical issue in mine planning, safety, and economics. In this study, the reliability of a hydraulic shovel was investigated through analysis of the number of failures of its hydraulic system. Failure data of the shovel, during one year of continuous operation, were obtained and preprocessed. Autoregressive integrated moving average (ARIMA) technique was employed for failure modeling and predictions. ARIMA showed to be a viable alternative to the traditional probability distribution fitting techniques. Mean absolute percentage error (MAPE) value of 2.5% was achieved for prediction of the number of failures by the best ARIMA model. Keywords: Mining shovel; hydraulic system failures; reliability; ARIMA.

## **Coal & Energy: Underground Mining Innovations**

**9:00 AM • Wednesday, February 18 • 503**

*Chair: R. Kudlawiec, Prairie State Generating Company, Windber, PA*

**9:00 AM**

### **Introductions**

**9:05 AM**

### **Integrated Longwall Solutions with Automation leads to Optimized Safety and Productivity**

*J. Haughey; Product Management, Joy Global, Franklin, PA*

Today's global mining operations are driving equipment suppliers to provide longwall mining solutions that limit the exposure of personnel to mining conditions, while pushing the need for increased productivity. Increased focus on worker safety from mining companies, regulatory bodies, and Joy Global's own Zero Harm practices are the main drivers, while an extremely competitive coal market has led to the need for increased productivity. Although these two concepts do not typically go hand in hand, through the use of automation, these goals are approachable. Equipment automation is not new to the industry as shearer and PRS automation systems have been in place for many years. However, safety and productivity optimization can only be achieved when there is complete system automation, which is possible when an integrated longwall solution is applied. System automation can lead to consistent production where remote personnel monitor the longwall and apply corrections in an ever changing mining environment.

**9:25 AM**

### **Proven Engineering Innovations for Underground Coal Mines**

*J. Helbig; GMS Mine Repair, Oakland, MD*

Underground coal mining can be hazardous and includes moving equipment, confined spaces, and heavy work. Experts agree the best way to reduce risk is to engineer out the problem. This presentation describes engineering solutions that have improved safety, production, and compliance in coal mines. Examples include a Cart System for 84" slope belt installation, a development for continual and improved rock dusting along beltlines and returns, and a remote-controlled, low-profile mining machine designed to drill, cut, pick, and load. It serves many operational purposes as well as cutting manholes and making underground belt conveyor rehab easier, safer, and faster.

9:45 AM

## Using A Mine Pool Reservoir to Augment Low Stream Flows in the Susquehanna River Basin

*T. Gray<sup>1</sup>, T. Smith<sup>2</sup>, S. Quinlan<sup>3</sup> and P. Milavec<sup>4</sup>; <sup>1</sup>Energy and Natural Resources, Tetra Tech, Inc., Pittsburgh, PA; <sup>2</sup>Energy and Natural Resources, Tetra Tech, Inc., Pittsburgh, PA; <sup>3</sup>GAI Consultants, Inc., Pittsburgh, PA and <sup>4</sup>Bureau of Conservation and Restoration, Pennsylvania Department of Environmental Protection, Ebensburg, PA*

The Susquehanna River Basin Commission (SRBC) implemented a consumptive use regulation in 1976. Using abandoned mine pools as reservoirs to compensate for consumptive use during periods of low stream flow. Coupled with treatment of the water to mitigate pollution could help restore the West Branch Susquehanna River watershed. The SRBC and Pennsylvania agreed that 15.7 million gallons per day (MGD) of water supply would be required to replace water withdrawn by users. Approximately 10 MGD of new water will be added by relocating treated water from the Lancashire No. 15 mine pool to find the remaining 5.2 MGD of needed water for the Susquehanna River Basin. The PA DEP along with the selected project team completed an evaluation of the central PA abandoned mine pools. Combining the Cresson 9, Gallitzin Shaft, and Argyle/Stone Bridge mine pools could produce the required 5.7 MGD during low flow periods. This project would substantially improve 5 miles of Sugar Run and 17 miles of Clearfield Creek. The project team is in the design phase of the Cresson AMD Abatement Project that will manage and treat AMD from these mine pools. This paper will provide a summary of the project to date.

10:05 AM

## Wireless, Battery Powered, Intrinsically Safe Atmospheric Monitoring Sensors

*T. Michaud; Strata, Sandy Springs, GA*

The latest in wireless battery powered atmospheric monitoring sensors provides the best in class pre and post accident mine situational awareness while providing a reduction of operational costs on a daily basis. This paper provides a recommendations and deployment data on how the latest in wireless AMS sensors can be deployed along with existing infrastructure to provide pre and post accident mine awareness. The paper will also provide actual data on the reduction of operational costs of wireless compared with traditional wired systems.

10:25 AM

## ARIES Research to Identify the Factors Responsible for Preventing Discharges from Pennsylvania's Bituminous Coal Mine Pools

*A. Iannacchione, J. Van Ness, G. Frank and H. Giocomin; Civil and Environmental Engineering, University of Pittsburgh, Pittsburgh, PA*

Seventeen underground bituminous coal mines in Pennsylvania were analyzed to determine the factors most critical in preventing unplanned discharges to surface waters. Mining maps, pi-

ezometer readings, core log data, water chemistry, and flow characteristics were obtained from each site. Three general classes of discharges are observed: a) horizontally through down-dip barriers containing coal and other fractured strata; b) vertically through overlying fractured strata barriers; and c) both horizontally and vertically through a combination of fractured strata. Eight conditions, having the potential to decrease the probability of discharge through barriers, are: 1. Extraction ratio ( $Re < 0.7$ ) 2. Hydraulic gradient ( $dh/dl < 0.1$ ) 3. Hydraulic conductivity ('k' for coalbed & adjacent strata) 4. Overburden ( $h > 250$ -ft) 5. Geology (no significant discontinuities) 6. Location of critical hydraulic barrier (horizontal barrier above drainage) 7. Barrier thickness measurements (precise knowledge of barrier size) 8. Pool elevation (highest potential mine pool elevation) The risk for unplanned discharges is lowered by achieving these positive conditions.

**10:45 AM**

15-010

## **Improved Safety For Ground Support Installation in Narrow Vein Mine Conditions With A Mechanized Bolter**

*W. Kendall; Research and Development, J.H. Fletcher & Company, Huntington, WV*

Narrow vein mining has traditionally been performed with hand-held "jackleg" equipment since mechanized equipment was too large for the selective narrow vein techniques. Traditional hand-held pneumatic equipment provides flexibility for small opening, narrow vein, development but requires operator exposure to certain inherent hazardous conditions. Mechanized equipment has the advantage to improve workplace safety and reduce operator exposure compared to hand-held equipment, and provide improvements to the health of the underground hard rock miners. This paper describes the equipment design and development process by J.H. Fletcher & Co. in conjunction with the Stillwater Mining Co. and provides results to demonstrate the improved safety of ground support installation in narrow openings, reduced miner exposure to hazards, and overall improved worker conditions. Three machines are currently operating successfully at 3 different mines in the USA and a 4th machine will be built during the 4th quarter of 2014 for use in Canada.

## **Coal & Energy: Ventilation Innovations I**

**9:00 AM • Wednesday, February 18 • 501**

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

**9:00 AM**

**Introductions**

9:05 AM

15-018

## **3-Dimensional Modeling of Fugitive Dust Dispersion in Idealized Open-Pit mines using CRADLE**

*T. Bhowmick, K. Raj and S. Bandopadhyay; Department of Mining and Geological Engineering, University of Alaska Fairbanks, Fairbanks, AK*

Fugitive dust control in high latitude open-pit mines is challenging due to (i) different atmospheric phenomenon resulting in complicated flow regimes, and (ii) lack of adequate solar insolation during prolonged winter seasons causing atmospheric inversion. In this study two idealized (One conical and one trapezoidal) 3-Dimensional open-pit mine geometries are simulated for different seasonal conditions using CRADLE CFD. In each scenario, fugitive dust particles varying in size (PM<sub>0.1</sub> to PM<sub>10</sub>) and concentration are generated at various locations of mine. The airflow is modeled using Standard Kappa-Epsilon Turbulence Model solved by RANS equation. The flow pattern of dust particles was solved by Particle Tracking module. The amount and location of dust inside the pit is reported at different time intervals.

9:22 AM

## **Ventilation Impacts on Spontaneous Combustion and Explosive Air Distribution in Longwall Gob using 3-D Physical Model**

*H. Jiang<sup>2</sup>, Y. Luo<sup>2</sup> and X. Zhai<sup>1</sup>; <sup>1</sup>Xi'an University of Science and Technology, Xi'an, China and <sup>2</sup>Mining Engineering, West Virginia University, Morgantown, WV*

Distribution of air movement in longwall gob plays an important role for identifying zones of spontaneous combustion and explosive air behind the longwall face. The air movement is largely governed by the overburden caving process and ventilation pattern. In order to gain a good understanding of the air movement in longwall gob using U-ventilation system, a 1:300 scale 3-D physical model is constructed for an experimental study. The physical model consists of four parts: overburden strata constructed with simulant materials, mining system, ventilation system and data acquisition system. As the strata subside with mining progress on the physical model, tracing gas is introduced in the intake entry. Tracing gas concentrations in the gob are measured at multiple pre-installed sampling points. Distribution map of the tracing gas in the gob at later mining stages is generated. The experiment enables the determination of air composition (in terms of concentrations of O<sub>2</sub> and CH<sub>4</sub>) distribution in longwall gob in later mining stage. Such information is useful for the analysis of potential hazards of spontaneous combustion and methane explosion.

9:39 AM

15-073

## Lessons Learned from Research About Methane in Coal Mine Gobs

*J. Brune, J. Grubb, G. Bogin, J. Marts, R. Gilmore and S. Saki; Colorado School of Mines, Golden, CO*

Most, if not all longwall gobs contain explosive gas zones (EGZs), i.e., zones of explosive methane-air mixtures that can cause – and have caused – mine fires and explosions. If the coal is prone to spontaneous combustion, oxygen penetration into the gob must be avoided. This paper summarizes the significant research findings from five years of computerized fluid dynamics (CFD) modeling research conducted at the Colorado School of Mines (CSM) under funding from NIOSH. CSM Researchers have developed CFD modeling techniques to identify where and under what circumstances EGZs can form in longwall gobs and how EGZ formation and oxygen penetration depend on the ventilation method, face and bleeder ventilation parameters, injection of inert gases and the operation of gob ventilation boreholes. Recognizing these explosion and fire hazards is an important first step in improving the safety of longwall mines. CSM modeling research has shown that EGZ formation can be effectively controlled by adjusting ventilation parameters, choosing the proper ventilation pattern and injecting inert gases where necessary.

9:56 AM

15-107

## Automation in Detection of Recirculation in a Booster Fan Ventilation Network

*M. Shriwas<sup>1</sup> and F. Calizaya<sup>2</sup>; <sup>1</sup>Mining Engineering, University of Utah, Salt Lake City, UT*

Recirculation is prohibited in many coal mining countries because of the fear that the re-use of return air would allow the build-up of air contaminants at the workings. The incorrect design and location of a booster fan in any ventilation network can create unsafe condition due to recirculation. The current approach to investigating recirculation using simulation software requires manual effort which becomes tedious in a complex and a large network. An algorithm-based C++ program was designed to detect the recirculation in a booster fan ventilation networks. This program needed an input file prepared from output file generated by any ventilation simulator. This program created an output file for recirculation. This program demonstrated the strong capability to detect the recirculation in a sample network and a coal mine ventilation network. The outcomes of this program were documented in this paper.

10:13 AM

## CFD Modeling of Dynamic Diesel Fumes Dilution

*A. Agasty and E. Clausen; Mining Engineering, Clausthal University of Technology, Clausthal-Zellerfeld, Germany*

Optimal auxiliary ventilation for the advancing galleries is necessary to keep the pollutants produced as a result of the mining cycle below the threshold limits. A suitable choice, keeping in mind the variable pollutant load over different stages, should not only effectively dilute the contaminants but also reduce the energy required by the system. One of the major dilution ventilation requirements, along with blasting fume dilution, is during the loading operation with the aid of diesel operated loaders. The dynamic behavior of diesel exhaust fumes generation, as a result of the loading and hauling out operations, need to be addressed with a time dependent ventilation system, or so called Ventilation on Demand. The presented study simulates the diesel fumes generation during loading and hauling operation using Computational Fluid Dynamics software ANSYS v. 14. Simulation of different ventilation models aids in planning for the ventilation strategy that best suits the requirement. The dynamic modeling is further used to decide the loader control for the production cycle from a 3 drift panel with one transfer point.

10:30 AM

15-105

## Effect of Scale of Premixed Methane-Air Combustion in Confined Space Using LES Model

*L. Wang, N. Aouad and J. Tien; Mining, Missouri University of Science and Technology, Rolla, MO*

Gaseous explosion is one of the most hazardous incidents in process industries and mining industries. The experimental research is both of high risk and cost. CFD technique is a reasonable alternative. The scaling effect on explosion parameters could be evaluated using a validated numerical scheme. By employing Gas-fill Length scaling factor (FLSF) and Hydraulic Diameter scaling factor (HDSF), the impact of dimensions on the explosion key parameter, the overpressure, was investigated. Eight HDSFs and five HDSFs were combined to cover a wide range of site-geometries. Experiments were conducted to evaluate the premixed combustion and turbulence models. Large Eddy Simulation (LES) turbulence model was proved more accurate than normal Reynolds' averaged models for scenarios on hand. Three major conclusions can be drawn from the results. (1) The overpressure increases as both FLSF and HDSF increases within deflagration regime. (2) For a length to diameter ratio greater than 54, detonation other than deflagration will more likely to happen in a stoichiometric methane explosion. (3) Overpressure increases as an increment hydraulic diameter of a geometry within deflagration regime.

10:47 AM

15-001

## **CFD Study of face Ventilation effect on Tailgate Methane Concentration and Explosive Mixture of Gob in Underground Longwall Coal Mining**

*J. Brune, S. Saki, J. Marts, R. Gilmore, G. Bogin and J. Grubb; Mining Engineering, Colorado School of Mines, Golden, CO*

Main purpose of ventilation design is to provide sufficient quantity and quality of air to the workers and to dilute methane and other contaminants. It is generally felt that sending more air to the longwall face will improve methane dilution on the face and in the tailgate. However, computational fluid dynamics (CFD) modeling efforts at the Colorado School of Mines in NIOSH-funded research have found that higher face air quantities sweep more methane from the gob into the tailgate area, thereby negating the dilution effect. Increased face ventilation also increases oxygen ingress into gob area, thereby increasing the amount of oxygen available to form explosive methane air mixtures in the gob. In this paper, a parametric study of longwall face ventilation will be presented. The paper will discuss the effect of varying the face air quantity on methane concentrations in the tailgate and explosive volume formation in gob. Counter to conventional wisdom, it appears that increased longwall face air quantities may increase the explosion hazard as they result in increased explosive gas volumes in the gob, along with increased methane quantities in the tailgate return.

11:04 AM

## **An Investigation of Mine Gas Stability in Sampling Containers Over Time Using Gas Chromatography Analysis**

*H. Dougherty, A. Haghighat, T. Jeter, K. Brashear, K. Luxbacher, H. McNair and E. Jong; Mining and Minerals Engineering, Virginia Tech, Blacksburg, VA*

Gas chromatography (GC) is the most widely used analysis technique for the qualitative and quantitative characterization of volatile compounds. This usage is derived from GC's ability to accurately quantify analytes to sub parts per trillion (PPT) level concentrations. Various sampling methods are available to collect mine air samples for processing using GC. In this study, four different sample containers regularly used in the mining industry are examined. These containers are multi-layered Teflon coated Mylar gas sampling bags, glass vacutainers, plastic vacutainers, and plastic syringes. Each container was filled with a known mixture of gases commonly found in subsurface mine atmospheres, such as methane (CH<sub>4</sub>), oxygen (O<sub>2</sub>), carbon monoxide (CO), and carbon dioxide (CO<sub>2</sub>). The performance of each container type is presented accompanied by a detailed explanation of the experimental methodology.

## **Coal & Energy: What I Wish I Would Have Learned in School**

**9:00 AM • Wednesday, February 18 • 502**

*Chair: N. LaBranche, Deswik, Brisbane, QLD*

**9:00 AM**

### **Introductions**

**9:05 AM**

### **Public Speaking: The Number One Fear in American Society**

*A. Campoli; Jennmar, Lexington, KY*

The art of public speaking is a learned skill that is critical to success in engineering and business. Engineering curriculum do not include public speaking or drama. Students are told to listen, read, and display acquired knowledge through written examinations. A common public speaking misconception is that accomplished speakers were born with these rare skills. Another misconception is that accomplished speakers enjoy the spot light. This presentation will focus on effective verbal communication techniques.

**9:25 AM**

### **What I Wish I Would Have Learned in School: Legal Issues**

*A. Abrams; Law Office of Adele L. Abrams PC, Beltsville, MD*

Engineers and safety professionals who work in the mining industry are often unaware that they have personal exposure to civil and criminal prosecution in cases brought by the Mine Safety and Health Administration, or financial exposure in tort actions arising from mine disasters. These professionals also may fill important roles, including those of expert witness or behind-the-scenes consultant, in significant MSHA matters. This session will explain the different legal theories of liability that can involve mining engineers and safety personnel, and provide case studies that illustrate do's and don'ts when participating in mine site inspections or accident investigations. The session will also provide basic information for those who wish to assist as experts in surface and underground matters, including tactical approaches to developing reports and plans, serving as a liaison between mine operator and MSHA in abating hazardous conditions, and testimonial issues. It will include proactive strategies for mitigating undesirable legal exposures in these situations.

9:45 AM

## Managing Up or Managing Your Boss

*G. Buchan; RCS Corporation, Pittsburgh, PA*

Managing-Up or managing your boss has been defined as - “to have the by-product of your efforts enhance the work of those you report to”. An immediate response may be why you would want to do this or who should do it. The purpose of this paper is discuss the who, what, where, when and how of Managing-Up and to include the concept of Managing-Across for those times when cross-functional and interdepartmental managing is critical. The paper will present strategies for handling bosses, understanding the needs of your supervisor and then several diverse examples of handling unique bosses in both a mine operation and corporate environment. Lastly, the concept of “managing across” will be presented as many professionals will most likely find themselves in the role of a department manager and the need to deal with peers in other departments.

10:05 AM

## How to Be Your Own Boss

*B. Arnold; PrepTech, Inc., Apollo, PA*

In addition to all of the licenses and taxes and paperwork it takes to set up a company, there are certain things that an “entrepreneur” needs to consider before embarking on a journey that can be both challenging and rewarding. Can I pay the mortgage? Will mom and dad feed me? But even more seriously, how do I market my services or products? Where do I get help with finances, accounting, and taxes? Is my business plan clear—do I have my elevator speech ready? This presentation will be based on a real-life example but will also offer tidbits from other sources that the author has relied on over the years.

10:25 AM

## Don't Be Afraid to Reinvent Yourself

*N. LaBranche; Deswik, Brisbane, QLD, Australia*

The ability to adapt and reinvent yourself is crucial in this ever changing world, both for the young and the young at heart. Whether you are forced to reinvent yourself through redundancy or have a vision of a different role or career path, thoughtful, deliberate steps are necessary to reach your full potential. Reinvention is a choice that needs to be consciously identified and explored, creating yourself a roadmap to get to your destination. Often our fears hold us back from taking that next step and acknowledge and analyzing those fears are important steps in overcoming them. This is the story of one mining engineer's journey to move past her fears, take charge of her future and find happiness along the way. In her 10 years of experience so far Ms. LaBranche has been an in-house Mine Planning Engineer for operations on 3 different continents, a Health & Safety Researcher and is now a Senior Mining Consultant for a Mine Planning Software Company. In this presentation Ms. LaBranche will share some lessons learned and a few of the trials and tribulations along the way.

10:45 AM

## Rookie mistakes - lessons execrably learned

*T. Arnold; Nevada Copper Corp, Yerington, NV*

Leaving school you are filled with such hope and determination that you are sure Morgan Freeman should be narrating your life. You have a wealth of knowledge teamed with a smidgen of common sense, and you are sure that you are going to be a huge success. But there will be failures. Some mistakes can be avoided. Many will be repeated. All will, eventually, be regretted. The author will share some common mistakes made by good people starting their careers in an attempt to minimize the disappointments along the way.

## Environmental: Responsible Mining Environmental and Social Risks III

9:00 AM • Wednesday, February 18 • 106

*Chair: C. McKeon, North Shore LIJ Health System, Superior, AZ*

9:00 AM

## Introductions

9:05 AM

15-102

## Responsible Mine Closure

*M. Javier; EnviroMINE, Denver, CO*

The impact of mine closure is perceived through a veil of compliance to human laws & regulations rather than the laws & equilibrium of nature. This condition motivates the present research. Understanding the cause-effects of mine closure defines levels of responsibility. From this understanding evolves our mine closure's legacy. Mine closure characterizes in perpetuity three aspects: future liabilities; level of competence technologies for extraction; and, usage of mineral resources. These aspects must be updated to a rationally appropriate level. This paper will address the following questions: Will the minerals remaining in the process of mine closure ever be recovered? Will the mine closure inhibit the availability of minerals to the next generation? How many mines are designed to perform a successful mine closure? Do we close the mines or do we close nature? Is it responsible to continue mine closures as we do them today? Is mine closure a complement of mine operations or a contradiction of mining? Do we need to perform mine closures, yet? This paper reviews mine closure practices & principles to equate with the level of responsibility to nature & the next generation.

9:22 AM

## **The Race that Isn't: How Industry Can Actually Help Drive an International Trend of Heightened Environmental Regulation in the Copper Mining Industry**

*L. Johnson; Georgetown University Law Center, Washington, DC*

In this paper, I discuss how the “race to the bottom” fears that helped shape much of modern American environmental law never came to fruition on an international scale, at least in the context of copper mining. The “race to the bottom” theory has been a basis for implementing federal regulations in the United States. It argues that a company will naturally choose to do business in a market where there are no regulations rather than doing business in a market where there are regulations that impose additional costs. However, an examination of the regulatory system of the United States and its top regional copper mining competitors shows a trend of heightened environmental standards alongside increased investment in the copper mining sector. Moreover, investment actually seems to be driving this trend in many respects. I will also discuss two possible explanations for this trend: the existence of the Equator Principles, which set minimum global standards for large investment projects, and voluntary environmental action on the part of individual companies who are looking out for their own interests. This paper was published in the *Georgetown International Environmental Law Review*.

9:39 AM

## **Early Warning System for Landslide Detection - Highway and Pipeline Corridor, Peruvian Andes**

*D. Gilbert; Minera Taboca, Lima, Peru*

Extreme consequences exist along a highway corridor leading to a large copper mine in the Peruvian Andes. If two landslides are activated, there is possibility of environmental damage caused by leakage of concentrate, and closure of main route into the mine. Geotechnical monitoring through 2007 included monthly monitoring of piezometers and inclinometers by a work crew, and visual monitoring by maintenance personnel. In terms of risk, this monitoring frequency was insufficient. The geotechnical and telecommunications departments at the mine, in coordination with a third party contractor, began to map options for transmission of an early warning system back to mine. This presented difficulties, in that the terrain was very rough, high altitude, and cellular coverage was non-existent. Additionally, fiber optic usage was ruled out, as technology was not viable. Technical challenges at the time included line of sight transmission, requiring installation of high repeater stations, via mule train. This article describes the base installation in 2008, and how it has evolved to present day, including in-situ inclinometers, GPS receivers, strain gauges, and meteorological stations.

**9:56 AM**

## **A Perspective on Mercury: Air Emissions, Water Discharges, the Environment, and Regulations**

*A. Martin; Mining, Foth Infrastructure & Environment, LLC, De Pere, WI*

Mercury is a common contaminant in both industrial air emissions and water discharges. It has particular toxicity to biota and humans and is classified as a persistent, bioaccumulative and toxic (PBT) substance. Its entrance to the food chain begins in lentic and wetlands ecosystems where mercury methylation occurs. Water quality standards reflect this: wildlife protective mercury standards in many states are expressed in units of nanograms per liter or parts per trillion. These extremely stringent water quality standards pose particular challenges to those holding permits or proposing a mining project. Federal and state rules addressing mercury emissions and discharges place significant pressure on the regulated community to invest in expensive pollution control strategies. The goal of this presentation is to provide an understanding of mercury issues as they relate to mining projects and the environment. Better understanding and description of the environmental impacts of a project's mercury emissions and discharges may assist in environmental review, permitting, and compliance for a mine from the perspective of both regulators and mine operators.

**10:13 AM**

## **Tribal Consultation Mining Educational Module**

*C. Lechner; University of Arizona, Tucson, AZ*

Tribes are beginning to play an active role in the decision-making process to disapprove or approve mining proposals, because tribes are aware of the potential negative and positive impacts of mining. As tribal land is often desired for natural resource extraction, tribes have an urgent and critical need for information that can protect them from exploitation and understanding tribal consultation, negotiation, and mineral rights so they can make an informed decision about resource development. A tribal consultation module is being developed for tribal colleges that include an understanding of tribal consultation, rights of indigenous peoples, United Nation Declaration on the Rights of Indigenous Peoples, free, prior and informed consent, and tribal sovereignty. This stand-alone educational module can be modified and adapted to different learning scenarios and objectives for different community college level learning environments, training for mining personnel, and has potential for use by impacted tribal communities. The modules feature hands-on activities, incorporation of technology, student and community involvement, discussion, and exchange of ideas.

10:30 AM

## Using Probabilistic Analysis To Establish Environmental Reserves

*M. Barkley and J. Forbort; ARCADIS, Lakewood, CO*

Generally accepted accounting principles require U.S. corporations to identify, quantify, and disclose their environmental remediation liabilities. As required by ASTM 2137-01, corporations develop a range of potential environmental liability costs using: 1) a “best case” scenario, where liabilities/cost are assumed to be minimal, 2) a “most likely” scenario where some liabilities/costs are assumed to require additional treatment, and 3) a conservative “reasonable worst case” scenario where more involved treatment and remediation are necessary. While the best case and reasonable worst case scenarios can be readily established, the selection of a most likely scenario can be arbitrary and relies heavily on the quality of the assumptions used in developing the costs. Probabilistic models have the ability to integrate the three above cost estimates and calculate a distribution of reserve costs. The use of a probabilistic model also allows for non-routine project or environmental risks to be included in the reserve estimation. A case study will be presented showing how this approach reduced a WV coal company’s selenium treatment reserves by approximately \$300 million dollars.

10:47 AM

15-111

## Sustainability on Mining Business

*O. Restrepo Baena and A. Delgado-Jimenez; Materials and Minerals, Universidad Nacional de Colombia, Medellin, Colombia*

Sustainability is a concept that involves several aspects like social, economy and environment. For the concept of sustainable mining is an action that involves to do more in social acceptance, distribution of welfare, an stable economy and the environment. Understanding the mining operation that creates a new state that is necessary to prepare and conduct searching for the best results in sustainability. The results of sustainable mining could be directed to achieve less net environmental impacts, more economic development through the transformation of the natural capital and the social acceptance as the result of good negotiations with the communities in the surroundings. To do that, one option is to create frameworks to planning the regional mining developments that allows the stakeholders to decide and develop different strategies to addresses the sustainability in a mining environment. Strategies based on the understanding of the whole mining business, the environment in which it operates, composed for a natural resources network that interact in a complex system, social system composed by different groups, communities and economies that could be subject to big transformations.

**11:04 AM**

## **Corporate Social Responsibility in the Extractive Industries: A Global Reporting Initiative-Based Approach for Measuring and Reporting Mining Activities in Developing Countries**

*J. Medina; Energy and Mineral Sciences, The Pennsylvania State University, State College, PA*

Corporate Social Responsibility (CSR) projects in the minerals extractive industries are commonly driven and implemented by the private sector. However nowadays the world is in a starting point for recognizing that the social commitment involved into the extractive sector must not be only addressed by mining or oil and gas firms. This paper presents models for measuring, controlling, and reporting CSR activities based on International standards and guidelines for economic, environmental and social practices. As a result of its mining investment boom during the last 10 years, South America provides a perfect scenario for exercising socio-economic solution models. As a consequence of this mining bonanza, social and environmental issues have also increased, demanding different and more responsible approaches. In this work, two different study cases will be presented, the first one studies how the Colombian government is approaching the challenges to implement a CSR policy in the country. The second one is a project case based on a study field in Peru.

## **Environmental: Sustainable Outcomes from Effective Stakeholder Engagement**

**9:00 AM • Wednesday, February 18 • 107**

*Chairs: J. Lucas, Cliffs Natural Resources, Hibbing, MN  
S. Fecht, ENVIRON International Corporation, Westford, MA*

**9:00 AM**

## **Introductions**

**9:05 AM**

## **Creating Employee Ambassadors to Strengthen your External Relationships**

*H. Barnum; Mining, HDR, Salt Lake City, UT*

Creating employee ambassadors to strengthen your external relationships How do you leverage the knowledge of your sustainable and environmental practices within to protect your external stakeholder relationships? Hear from mining communications strategist, Heather Barnum, the value of creating a culture of employee ambassadors who are encouraged and confident to share your goals among their personal social networks. From communications tools and technology, messaging and challenges, learn strategies to apply in your stakeholder engagement and employee culture, including: -Create an engaged and positive work environment where employees are recognized and involved and understand their personal contribution to the

organizations' external relationships -Create sustainable programs and tools that will directly improve safety, environmental impact and productivity -Manage rogue employees from unauthorized media or social media chatter -Maximize your investment in external stakeholder engagement -Align external messages and priorities with internal communications -Reduce barriers of site/facility isolation and build a central employee community through strategic redundancy

**9:25 AM**

## **Mapping Stakeholder Engagement to Successfully Promote Sustainable Development**

*P. Castaños<sup>2</sup> and V. Morgan<sup>1</sup>; <sup>1</sup>Communications, Goldcorp Inc., Vancouver, BC, Canada and <sup>2</sup>Corporate Social Responsibility, Goldcorp Inc., Vancouver, BC, Canada*

A robust stakeholder engagement process is required at all stages of the mining lifecycle to promote sustainable development alongside mine development and operation. The process needs to identify the stakeholders, define the goals and objectives shared with them, develop a strategic engagement plan, ensure there are adequate resources, and understand the stakeholders' areas of influence and interests. It must also take into consideration key contextual facets, such as levels of power, technical capacity, ability for conflict resolution, access to resources, leadership ability, and the formal and informal interrelationships between stakeholders. Furthermore, it must be founded on geopolitical and economic assessments prior to engagement and permanent and ongoing monitoring during and after an engagement. While there is no blanket formula, stakeholder engagement is the core element to producing sustainable development outcomes. To be successful, the mining industry must embrace having implementation plans that actively involves those concerned and affected by its operations and closure.

**9:45 AM**

## **Effective Stakeholder Engagement in NE Minnesota**

*R. Learmont<sup>1</sup> and J. Marinucci<sup>2</sup>; <sup>1</sup>Solutions and Strategies Group LLC, Warba, MN and <sup>2</sup>Short Elliott Hendrickson Inc., Virginia, MN*

Northeastern Minnesota's mining industry produces more than 70% of the iron ore produced in the United States and accounts for 30% of the regional economy, successfully coexisting with non-mining activities. Effective stakeholder engagement and responsible land and resource management is integral to mining with best practices extending through the full mining cycle. This paper provides examples of effective stakeholder engagement and responsible land and resource management in northeastern Minnesota including legal and regulatory structure, best mining and reclamation practices, resource conservation and protection, technology development, and cooperative and collaborative actions and programs. An environment is created in which elements of the physical and biological environment, financial integrity, and industrial technology sustainably coexist over an

extended time period. The current structure has evolved over more than 100 years and is expected to continue to evolve through stakeholder collaboration and cooperation.

**10:05 AM**

## **Sustainable Water Supply for a Mine Expansion in Peru**

*M. Hardin; Environment & Sustainable Development, Freeport McMoRan Inc., Phoenix, AZ*

Freeport-McMoRan Inc. planned to expand its Cerro Verde mine near Arequipa, Peru, requiring new water supply. Sited in an arid region, the population depends on water from the local Chili River, already fully licensed. Water needs of new mines in Peru have been a social flash point. As such, dialogue with local communities on new water use by the project was needed to address social risk. Arequipa does not treat sewage, discharging raw effluent to the river. Downstream farmers are impacted by health issues and inability to export due to this contamination. During CVPUE planning, construction of a Waste Water Treatment Plant (WWTP) for Arequipa and use of treated effluent in mine operations emerged as a solution with sustainability benefits and possible public acceptance. However, local government and the farming community had concerns linked to public expectations for the proposed WWTP and water availability/use. Engagement led to negotiated solutions, helping protect all interests while maintaining the schedule of key CVPUE permit approvals.

**10:25 AM**

## **One Size Does Not Fit All; Comparing Stakeholder Engagement Between Three Federal Agencies**

*L. Watson<sup>1</sup>, V. Porter<sup>2</sup> and R. Badger<sup>2</sup>; <sup>1</sup>Policy and Planning, Merjent Inc., Minneapolis, MN and <sup>2</sup>Environmental Planning, URS, Salt Lake City, UT*

A three-person panel discussion comparing the different stakeholder engagement practices used by three federal agencies during the environmental permitting process. The panel will compare stakeholder engagement mechanisms and processes used by the U.S. Forest Service (Forest Service), Bureau of Land Management (BLM), and U.S. Army Corps of Engineers (Corps). The panel will provide insight to each agency's guidance and process for stakeholder participation and implementation during the environmental permitting process for mining projects. The panel will discuss scalable lessons learned during the environmental permitting phase for U.S. mining projects.

10:45 AM

## **Newmont's Long Canyon Project provides Long Term Drinking Water Source to Local Communities**

*D. Anderson; Sustainability and External Relations, Newmont Mining Corporation, Elko, NV*

The proposed Long Canyon Project is a Carlin-type gold deposit located on BLM and Newmont property in the Pequop Mountains between Wells and West Wendover Nevada. The Project will be developed as an above the water table open pit, producing approximately 176,000 ounces AU for 10 years. One environmental concern identified was the location of a spring (Big Springs) located beneath the proposed pit which is utilized by local communities as a municipal drinking water supply. Recognizing the concern early in the Project planning efforts, Newmont engaged with key stakeholders including Wendover long before the permitting process initiated. The Cities expressed concern with proposed activities located "on top of Big Springs". Through collaboration, an alternative drinking water source and an agreement for the management of Big Springs were reached. The agreement's key components include financial and non-financial commitments. The agreement paves the way for Newmont and Wendover, as partners, to develop the Long Canyon Project while affording the Cities a long-term stable source of drinking water and related infrastructure to support community growth and sustainability.

## **Environmental: Water Treatment III: Arsenic, Selenium and Other Contaminants**

9:00 AM • Wednesday, February 18 • 105

*Chairs: D. Stanley, Rio Tinto, Superior, AZ  
K. Martins, Chem Hill, Santa Ana, CA*

*Sponsored by: Veolia Water Solutions*

9:00 AM

## **Introductions**

9:05 AM

## **Assessment of Different Technologies for Arsenic Removal and the Impact of Water Quality**

*K. Banerjee and S. Muddasani; Process Department, Veolia Water Solutions and Technologies, Moon Township, PA*

Studies were conducted to develop a comparative assessment of arsenic removal technologies, and to assess their performance in the presence of phosphate, vanadium, sulfate and silica. The objective of this work was to identify the impacts of water quality and to define the process parameters that would maximize the arsenic adsorption capacity. Iron modified activated alumina (AA-FS50), granular ferric hydroxide (GFH), granular ferric oxide (GFO), a titanium-based media, and IX resin

were tested as adsorbents. Additionally, iron coprecipitation and adsorption followed by high-rate sand-ballasted settling technology was piloted. Each adsorbent was characterized according to its physical/chemical properties, including particle size, surface charge, pH of zero-point charge (pHzpc), surface area, etc. Results revealed that pH has a significant impact on the adsorption capacity of each media. Phosphate had a small impact on AA-FS50; the capacity of the GFO was significantly impacted by phosphate and vanadium; a similar impact was observed for the GFH media. The ion exchange process was severely impacted by the presence of sulfate. Detailed results and a cost comparison will be discussed.

**9:25 AM**

## **Interim Water Treatment at the Faro Mine, Yukon, Canada: The 10-Year Plan**

*J. Stefanoff<sup>1</sup> and K. Furlong<sup>2</sup>; <sup>1</sup>CH2M HILL, Spokane, WA and <sup>2</sup>Assessment and Abandoned Mines, Government of Yukon, Whitehorse, YT, Canada*

CH2M HILL is assisting the Government of Yukon with reclamation and water treatment at the now closed Faro Mine in Yukon, Canada. This open pit mining complex operated between 1969 and 1998 and was once one of the largest lead-zinc producers in the world. To meet local regulations, the mine wastewater requires treatment to reduce aluminum, cadmium, copper, lead, nickel, and zinc. While long-term water treatment is to be conducted using a 44 ML/day (8,100 USgpm) high density sludge process, that system will not be operational for about 10 years, necessitating an interim system. The development and screening of treatment approaches is described, as well as the rapid design, construction, and start-up of the selected 33 ML/day (6,000 USgpm) system. This consists of two parallel trains of prefabricated skid-mounted equipment utilizing lime neutralization, resulting in alkali precipitation of metals, followed by sand-ballasted clarification. The system is housed within a fabric building, providing an economical means to withstand the harsh northern environment.

**9:45 AM**

15-143

## **Reducing Life Cycle Costs of Active Treatment for Selenium and Arsenic in Mine Waters and Metallurgical Waste Streams**

*D. Kratochvil, P. Littlejohn and O. Lopez; BioteQ Environmental Technologies, Vancouver, BC, Canada*

Stringent regulations and increased arsenic presence in ore bodies being exploited have created the need for cost effective and environmentally compliant technologies to remove selenium and arsenic from mine waters and metallurgical waste streams. Existing treatment methods have high life cycle costs and/or produce residues that, due to their unknown stability over the long-term, may represent future liabilities. This results in high compliance costs and uncertainties which negatively impact existing operations and projects in permitting. Selen-IX® is a new ion exchange based process that selectively removes selenium from mine impacted waters down to 1 ppb while generating a stable inorganic iron-selenium product. Results of pi-

loting completed on streams generated from coal and copper-gold deposits are presented along with preliminary equipment sizing and life cycle costs of full scale treatment. Two examples of commercial systems for arsenic removal are presented. One of these uses selective ion exchange while the other uses sulphide precipitation. The benefits of these treatment methods for existing projects are discussed based on recently completed engineering designs.

**10:05 AM**

## **Changing Water Treatment Strategies for Hecla Limited's Grouse Creek Project in central Idaho**

*B. Tridle; Environmental Technical Services, Coeur d'Alene, ID*

Hecla Limited has operated water treatment facilities at Grouse Creek through mining, care/maintenance and reclamation activities. Grouse Creek was placed into care/maintenance status and water treatment focused on metal concentrations on site including cadmium, copper, lead, mercury and zinc. Water treatment was refined to target metal reduction through lime precipitation. Variable flow ranging from 250 gpm to over 4,000 gpm created problems with treatment efficiency. Future design considerations for flow were necessary to stabilize the treatment process. During site reclamation, source waters to the treatment facility were rerouted to reduce flow to the facility. A large 45 MG lined pond was developed onsite to store spring runoff. With this storage in place Grouse Creek gutted the existing facility and rebuilt it with improved lime precipitation, coagulation/flocculation, gravity settling (incline plate clarifiers) and rotating disc filters for polishing. This current system operates with flow ranging from 250 gpm to 2,000 gpm. Grouse Creek has successfully transitioned through the stages of this project by adapting water treatment technologies to meet changing site conditions.

**10:25 AM**

## **Online Total Arsenic and Selenium Combination Analyzer for Mine Wastewater Remediation Process Control**

*V. Dozortsev; Aqua Metrology Systems, Sunnyvale, CA*

Various mining activities are among major anthropogenic sources of arsenic and selenium release in the environment in many parts of the world and US. Due to complex redox chemistry of both arsenic and selenium their remediation from mine influent is a difficult task. Integrity of water remediation process critically depends on availability of real time information on contaminant level at different stages of the treatment process. Obviously, traditional time consuming laboratory analysis of representative samples can not meet requirements of modern process control. Timely and informed process control decisions can be only achieved through reliable real time process monitoring using online process analyzer. This paper discusses applicability of new combination arsenic and selenium analyzer to mining influent remediation process monitoring. Metal specific analyzers capable of detecting both metalloids have been previously reported. However, integration of two analytical methods

in single measurement device has been difficult. Novel versatile analyzer developed allows sensitive detection of both elements using the same probe and chemical method.

**10:45 AM**

## **Technological Advances in the Simultaneous Removal of Arsenic and Antimony from Mine Influenced Waters**

*S. Billin, M. Spieth and S. Barton; Linkan Engineering, Elko, NV*

Significant advancements have been made in mine water arsenic treatment to the point where these processes are predictable, reliable and effective. Modern hard rock mining routinely encounters sulfide mineralization where both arsenic and antimony are present in copious aqueous concentrations. These elements behave similarly with regard to toxicity and exhibit some similarities in the reactivity required for treatment and removal. However, multiple oxidation states and varying optimal pH treatment regimes can make simultaneous removal of arsenic and antimony complicated. This new focus on antimony requires existing mine water treatment systems to evaluate the opportunity to implement single step removal of both arsenic and antimony as an alternative to costly addition of a two-step process. This presentation details new research trials conducted to identify the several key design variables in both single step and dual step arsenic-antimony treatment systems. This work identifies the appropriate design criteria for simultaneous removal as well as highlights the situations when dual-step treatment is required.

## **Industrial Minerals and Aggregates: Innovation in Water and Energy Savings**

**9:00 AM • Wednesday, February 18 • 102**

*Chairs: S. Ravishankar<sup>1</sup>, Cytex Industries, Stamford, CT  
V. Gupta<sup>2</sup>, FLSmidth Inc., Midvale, UT*

**9:00 AM**

### **Introductions**

**9:05 AM**

### **Cluster Formation in Kaolinite Suspensions**

*J. Liu, C. Lin and J. Miller; Metallurgical Engineering, University of Utah, Salt Lake City, UT*

The behavior of kaolinite suspensions is of significant importance in many areas of technology, including mineral processing, specifically flotation and dewatering processes. The interesting surface chemistry of anisotropic kaolinite particles accounts for the complex interaction of these flat plate particles (~300nm in size) and the formation of clusters with unique structure. A Brownian dynamic simulation technique was used to study kaolinite particle interaction as a function of pH and ionic strength, considering both van der Waals and electrostatic

forces for cluster formation. Relatively large clusters of kaolinite particles (~2 microns in size) are formed at low pH (pH 4) with exposed silica face surfaces. The size, structure, and water content of the simulated clusters are described. In contrast well-dispersed particles are observed at higher pH (pH 8). Experimental validation of the cluster size and structure was accomplished by photon correlation spectroscopy, by SEM imaging with a WETSEM cell, and by 3D imaging using X-ray Micro CT.

**9:25 AM**

## **A Phosphate Mine Water Model Utilizing the GoldSim Modeling Tool**

*R. Davis<sup>1</sup> and G. Oswald<sup>2</sup>; <sup>1</sup>Cardno, West Valley, UT and <sup>2</sup>The Mosaic Company, Lithia, FL*

The volume of water handled every day at a Florida Phosphate mine is greater than that of any other substance; including the phosphate. An average size mine is nearly always pumping several hundred thousand gallons per minute of water around the property. Prudent management of the water volume and its chemical composition is critical to the sustainability of this business; any failure to do so has the potential for consequences well beyond the property line of just that mine. Historically, management of the water has relied upon the human judgment of a few highly experienced individuals, and while they have done a very good job, the industry faces stricter effluent limitations in the near future. To ensure the mine is properly positioned to comply with these stricter limits and a desire to further improve water management decisions, a water model was created for Mosaic. This pilot model was created to determine if the complexities of a typical phosphate mine can be successfully reduced to a mathematical simulation. The presentation will discuss how this model was created and validation of the model comparing model predictions with actual results.

**9:45 AM**

## **Energy and Water Intelligence in Mining Operations - Big Data, Smart Sensors and Analytics**

*R. Marril<sup>1</sup> and F. Mielli<sup>2</sup>; <sup>1</sup>Schneider Electric, Denver, CO and <sup>2</sup>Schneider Electric, Alpharetta, GA*

Telemetry, embedded sensors, meters and all the objects surrounding the miners life are getting smarter ; However, some market / industry researches estimate that less than 1% of devices able to deliver data are still disconnected and indicated that big data is among the top trends that are going to impact direct the mining industry and the mining business. The market knows that is technically possible to plug these devices and unleash all this data to the system, but, the main question is: How to transform this huge amount of data into useful information and drive decisions or trigger events The objective of this paper is to discuss today's available technologies, main challenges and how to deliver water and energy decisions: Gathering, connecting and putting huge datasets into context.

10:05 AM

## **Novel Routes for Selective and Total Flocculation of Mineral Solids in a Produced Fluid Matrix**

*C. Aften and N. Tang; R&D, ChemEOR Inc., Covina, CA*

Enhanced Oil Recovery (EOR) techniques have very successfully demonstrated, increase in the hydrocarbon yield when the produced fluid separates into the oil and the aqueous phase. This aqueous phase is then treated either for disposal or to be recycled into the system. This phase is a complex matrix composed mainly of polymers, mineral solids, residual base, residual oil and sometimes surfactants. If disposal approach is chosen, the mineral solids must be flocculated by a method that balances density, dewaterability, process variation and cost. However, if the fluid needs to be recycled, the task is more challenging because the conventional chemistries that are used for flocculation interfere with the polymers that are already present, thereby changing both, the physical and chemical composition which in turn reduces the effectiveness of the recycled matrix. In this paper, we describe new and novel routes to selectively flocculate mineral solids from a polymer flood matrix while leaving the high molecular weight polymers intact, thus minimizing the effectiveness of the recycled fluid. Also, total flocculation of the aqueous components in the produced fluid can also now be achieved.

10:25 AM

## **New and Simple Techniques for Boron Removal from Waste Waters**

*C. Aften and J. Zhang; R&D, ChemEOR Inc., Covina, CA*

Boron is widely distributed in the environment in the form of boric acid or borate salts, and can be a micronutrient for living organisms. Excess amounts of boron could be toxic to both plants and animals. The WHO recommendation on boron levels in drinking water is  $< 0.3$  mg/L. The main source of boron entering the waste water streams is due to the increase in use of surfactants, and other chemical technologies in all industries including mining and oilfield production. Currently, very few options are available for boron removal, which include reverse osmosis (using membranes), co-precipitation/adsorption, and ion-exchange. Among these, some are not very economical and some are not very selective, for example, ion-exchange is effective in boron removal, but it also removes other desired species. Therefore, a need exists for the development of new techniques that can remove boron selectively, effectively and economically. We have developed new methods in the laboratory that show promising trends in selectively reducing boron concentrations in waste waters obtained from oilfield industries. Design of Experiments were used in order to identify and optimize the process and chemistry.

10:45 AM

## Thermoelectric Generation for Fuel Efficiency

*M. Scullin<sup>1</sup> and H. Hansen<sup>2</sup>; <sup>1</sup>Administration, Alphabet Energy, Hayward, CA and <sup>2</sup>Communications, Alphabet Energy, Hayward, CA*

Alphabet Energy is the world's premier thermoelectrics company and the creators of the first low-cost thermoelectric generator. Our thermoelectric generators make waste heat valuable by turning hot exhaust gases into electricity and into immediate fuel savings. Thermoelectrics are solid materials that convert waste heat into electricity. At the core of Alphabet Energy's innovation are a number of proprietary materials and processes including silicon nanowires and tetrahedrite. Alphabet Energy's mining and oil & gas customers recognize the value of incremental improvements in operating efficiency and appreciate the new-found cost savings associated with power generation from waste heat and hot exhaust gases. Additionally, these same customers value Alphabet Energy's low-cost, turnkey products that deliver rapid ROI with no additional downtime for service or maintenance. Because thermoelectrics are solid state, Alphabet Energy's products have been optimized for strength, reliability, and simplicity. These after-market technologies are ideally suited for remote applications where fuel is expensive and where energy efficiency is highly valued.

## Mineral & Metallurgical Processing: Comminution II: Mechanical and Electrical Developments

9:00 AM • Wednesday, February 18 • 711

*Chairs: A. Giblett<sup>1</sup>, Newmont, Subiaco, WAS, Australia  
M. Dennis<sup>2</sup>, FLSmidth USA Inc., Midvale, UT*

9:00 AM

## Introductions

9:05 AM

15-042

## Closed Side Setting Measurement and Mainshaft Installation

*T. Shumka and M. Druckenmiller; Crusher Vision Inc., Kelowna, BC, Canada*

A patent pending system and method for measuring the closed side setting (CSS) on gyratory crushers. It will give crusher operators accurate and reliable measurement for the CSS in a live operating environment. Measurement data can be collected in five minutes allowing for fast adjustment of the mantle position. The advantage of this system is that it is permanently mounted at the crusher location. The operator can turn the system on and off as many times as they like throughout the day. The goal is to maintain a constant CSS gap based on production and maintenance criteria to help streamline operations and enhance safety efficiencies. The safety factor enhancement with this system is

extreme. It does not require the use of overhead cranes, cleaning out the crusher, lowering people into the crusher or having the operator lower paint cans or lead balls into the crusher pocket while the crusher is in operation for measurement. Current methods used to position the crusher mantle into its place was to have a worker/spotter underneath the suspended mantle. The solution was to provide real time video feed to a laptop or tablet that the crane operator used to guide the mantle into place.

**9:25 AM**

15-146

## **Low Speed Asynchronous Motors for Minerals Milling Applications**

*V. Matthews; Minerals, Siemens, Alpharetta, GA*

Traditional motors for milling technology has relied on either Wound Rotor Induction, Low Speed Synchronous Motors, or Asynchronous Induction Motors with mechanical gear reducers. A new alternative is now offered: The Low Speed Asynchronous Motor. This alternative provides the benefit of reduced complexity, higher efficiency and both lower capital and operating costs. The combination of the Low Speed Asynchronous Motor with an Adjustable Frequency Drive affords the benefit of flexibility in grinding at different speeds and controlling the rate and energy used during start up and shut down. In addition, operating protections can be added that cannot exist in motors connected directly to the utility. A comparison of different motor types for milling applications is provided. This comparison will analyze initial cost, cost of ownership, energy use, complexity and reliability. The result is intended to provide a reference for motor choices in milling applications. In addition, the actual application of this technology at a mine site will be presented.

**9:45 AM**

15-148

## **The Optimization of a Cyclone Pump Electrical Drive System**

*L. Galarza; Minerals, Siemens, Alpharetta, GA*

Cyclone feed pumps are a critical component in the particle separation process for ore processing. Traditional system design consists of a pump coupled to a mechanical gearbox, coupled to a motor and then sometimes connected to an adjustable frequency drive (AFD). A new integrated drive system has been developed and successfully commissioned in multiple installations, it eliminates the reducer gear between the motor and pump and all corresponding maintenance. An adjustable frequency converter is installed to control the motor to run at the impeller speed; it omits the friction losses of the gear reducers, the drive operates at variable speed supporting at same time adjustment of pulp flow to the process changes resulting in significant energy cost savings. The integration of the drive system is analyzed on the basis of important considerations that must be optimized to provide the desired result. In addition, the successful commissioning in an actual mining location is discussed along with an evaluation of actual versus theoretical savings.

10:05 AM

## Zero Maintenance Mill Lining Technology: Metal Magnetic Liner for Ball Mills

*X. Jiang<sup>1</sup>, J. Marin<sup>1</sup>, M. Zhao<sup>2</sup> and C. Bon<sup>3</sup>; <sup>1</sup>Eriez Manufacturing Co., Fairview, PA; <sup>2</sup>Industrial Trade Company, Beijing, China and <sup>3</sup>Polimin, Santiago, Chile*

The ball mill is the critical equipment for mineral processing plant. Reliability of ball mill is the key for daily operation. With a unique design of the Eriez- JinFa metal magnetic liner (MML), over 600 ball mills have been installed with Eriez-JinFa MML worldwide. MML are manufactured by embedding the magnet into an abrasion-resistance alloy. It is easy and safe to install. It runs many years without any maintenance. The MML is attracted to mill shell or head by magnetic force. The fine ball chips or magnetite fill up all gaps, preventing ball chip to wedge into the back of liner and sealing up the whole mill, and eliminating leakage and back washing wear. A comparison test between MML and conventional steel liner was performed at a iron ore processing plant. It has been found that throughput has increased 2.96% while power consumption decreased 5.79%. The features and mechanism of MML are discussed.

10:25 AM

15-147

## Increasing Availability Through Advanced Gearless Drive Technology

*C. Dirscherl, T. Roesch and V. Matthews; Minerals, Siemens, Alpharetta, GA*

Declining ore grade, leading to increased material transport and plant throughput requirements, is one of the major challenges in the current mining environment. This is accompanied by rising energy and labor costs, decreasing plant productivity and emphasizing the requirement for highest plant availability. A new technical solution answers this problem with the latest gearless technology for both conveying and grinding. Gearless drive solutions are surpassing the mechanical limits of conventional drive systems serving to utilize the principle of economies of scale. By elimination of various components of the drive train, maintenance activities and spare parts inventories are reduced and energy efficiency and reliability are significantly improved. These advantages have resulted in a class-leading availability of the gearless drive technology of 99.46 to 99.71%. This data is confirmed by real operational data from the Antapaccay mine in Peru. Antapaccay is the first plant worldwide to use gearless technology for both conveyence (transport) and grinding applications.

## Mineral & Metallurgical Processing: Research and Characterization

9:00 AM • Wednesday, February 18 • 709

*Chairs: T. Bhambhani<sup>1</sup>, Cytec Industries Inc., Stamford, CT  
K. Mills<sup>2</sup>, Newmont Mining Corporation, Englewood, CO*

9:00 AM

## Introductions

9:05 AM

### **Aqueous Solution Species Effects on Mineral Surface Chemistry and Flotation Recovery in Complex Ores**

*R. Farinato and D. Nagaraj; IPS, Cytec Industries Inc., Stamford, CT*

The influence of aqueous species and their reactions in flotation pulps and near aqueous-mineral surfaces can be significant to the point of dominance in flotation operations on complex, practical ores. Determining quantitative in situ information about this panoply of chemical species (aka water chemistry) and interphases in a complex ore suspension remains an important challenge that would benefit technical improvements in commercial scale mineral flotation. In this paper we discuss the use electrochemical and aqueous chemical methods to investigate the phase behavior and mineral surface chemistry relevant to flotation of several different complex ores, including those for the recovery of copper, gold, molybdenum and PGM minerals.

9:21 AM

### **Surface Chemistry of Bastnaesite Flotation with a Lauryl Phosphate Collector**

*W. Liu, X. Wang and J. Miller; Metallurgical Engineering, University of Utah, Salt Lake City, UT*

Bastnaesite is a major mineral resource of importance in the production of rare earth materials. Present flotation practice uses a reagent schedule which typically includes fatty acid or hydroxamic acid as collector. Collectors for bastnaesite flotation have been discussed in the literature including surface chemistry considerations. Results from contact angle and micro flotation experiments for bastnaesite are reported using potassium lauryl phosphate as collector and the results are compared to results with hydroxamic acid as collector. Initial evaluation suggests that potassium lauryl phosphate may be a promising collector for bastnaesite flotation.

9:37 AM

### **Fundamentals of Hematite Agglomeration Using Cornstarch Binders**

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

Cornstarch has been proposed as an iron ore pellet binder for several decades. While it leads to good wet- and dry-ball properties, cornstarch can lead to weak preheated and fired pellets. Additionally, cornstarch can lead to sticky green-ball surfaces which impedes controlled ball growth and increases levels of dust and fines. Consequently, many types of materials have been proposed as additives for starch binders. Are certain additives more effective than others? How do the additives enhance (or lower) pellet strengths? What role(s) do the additives serve

during agglomeration? This presentation shows the effects of several additives, including sodium carbonate and sodium hydroxide, on hematite agglomeration. Dry ball strengths strongly correlated to the zeta potential of the hematite concentrate. Additionally, experimental results show that the starch binder used in these tests concentrated near the dry ball surface.

**9:53 AM**

## **Surface Area of Exposed Grains in Multiphase Particles**

*Y. Wang, C. Lin and J. Miller; Metallurgical Engineering, University of Utah, Salt Lake City, UT*

High Resolution X-ray Micro CT (HRXMT) systems have been used for 3D quantitative examination of multiphase particulate systems. Exposure analysis, one of the most important applications of HRXMT, is of particular interest since such textural considerations will help define the limits of flotation efficiency. However, due to inaccurate segmentation and the partial volume effect, valuable mineral grains may appear to be partially or entirely wrapped with a thin layer of gangue minerals. In this regard, the exposed grains will be misclassified as gangue, and for this reason, it is difficult to measure the surface area of exposed grains accurately. To solve the problem, Trainable Weka Segmentation has been introduced to improve image segmentation. At the same time software based on the computation of boundary characteristics in a multiphase particle has been developed to correct for the partial volume effect and reveal the exposed area of valuable mineral grains. With these new procedures for 3D image analysis, the valuable mineral grains are exposed as they actually are, and determination of the exposed surface area is demonstrated and discussed.

**10:09 AM**

## **Data Fusion Using Near-Infrared and Elemental Data – a Novel Technique for the Creation of Quantitative Predictive Models to Improve Mineralogical and Metallurgical Processing**

*D. Shiley and B. Curtiss; PANalytical NIR, Boulder, CO*

Near-infrared (NIR) spectroscopy is a useful tool for the prediction of metallurgical responses related to ore mineralogy. NIR is a molecular technique and the spectra are the result of molecular bonds and structure. Quantitative models can be produced to provide a real-time prediction of the mineralogy or metallurgical response using NIR spectral data. However, many minerals are not spectrally active in the NIR region so the use of NIR cannot normally be used to predict these minerals or metallurgical responses related to these minerals. Likewise elemental data poorly describes the minerals responsible for the metallurgical response. Due to the ever increasing use of elemental data either from ICP, XRF or LIBS a more complete description of ore samples could be obtained by combining NIR spectral data with the elemental data available for these samples. We have investigated creation of models using spectral and elemental data combined in a single multivariate model. Models developed for many key minerals significantly improve when the elemental and spectral data are combined using this approach.

10:25 AM

## **Online Grade Control in Mining by Energy-Dispersive X-ray Fluorescence – New Approach to Real Time Results**

*A. Buman, K. Behrens and D. Pecard; Bruker-AXS, Bruker, Madison, WI*

At present the analysis of samples in mining operations takes minimum 30 minutes if the XRF units are located close to the mineral beneficiation plant or up to several days if the samples needed to be sent to an external laboratory. Latest trend is to bring the analyser closer to the process and to integrate it so the analysis can be done continuously. Latest developments in energy-dispersive X-ray fluorescence spectrometry have offered the chance to develop dedicated EDXRF spectrometers for on-line applications in mining and coating. State of the art silicon drift detectors, better multichannel analysers plus more brilliant X-ray sources are leading finally to better analytical precision. This enhanced analytical performance paired with the compact size and low installation cost makes modern EDXRF instruments the ideal choice for online process control. The analysis of low and high grade iron ores and the separation from waste rock according to the cut-off levels is quickly possible within seconds. Copper ores and the final concentrates can be quickly controlled, the decision to feed the mined material to the flotation can be done close to the process improving the productivity.

## **Mineral & Metallurgical Processing: Separation: Flotation: Industrial Applications**

9:00 AM • Wednesday, February 18 • 710

*Chair: S. Miskovic, University of Utah, Salt Lake City, UT*

9:00 AM

## **Introductions**

9:05 AM

## **Next Generation Wemco Flotation Machine Development**

*K. Caldwell, K. Rahal and T. Olson; Research, FLSmidth, Midvale, UT*

A study to test new designs of rotors, dispersers, and hoods for the Wemco self-aspirating flotation cell was conducted. Through a series of laboratory, pilot scale and computational fluid dynamics assessments, a modified design to improve flotation recovery was found. A design of experiments matrix was used to determine the effects of combinations of new rotor, hood and disperser designs. It was determined that the disperser had the greatest impact on recovery. One configuration, which increased the amount of shear around the rotor was found to have much higher flotation rates. A series of dispersers were designed to gradually increase the amount of shear in the rotor-disperser region. This comparison showed that as the shear was increased the flotation recovery also increased.

The top designs will be tested in a 1.5 m<sup>3</sup> pilot flotation cell. Bubble size, recovery by size, and flotation kinetics were recorded and compared. CFD results supported the laboratory findings, showing an increase in particle attachment for the high shear conditions. The CFD was also able to accurately predict changes in the water velocity in the draft tube for different configurations.

**9:22 AM**

## **Development and Testing of the Largest Flotation Machine - 600 Series SuperCell™ from FLSmidth**

*D. Lelinski, Y. Yang, K. Caldwell, T. Baker and M. Jespersen; FLSmidth, Midvale, UT*

The economies of scale are forcing flotation cells to keep getting bigger – and more efficient. Until recently, the FLSmidth 300 Series SuperCell™, developed in 2009, was the largest in the world with a capacity of 300-350m<sup>3</sup>. But in 2011, FLSmidth decided to take this product line to the next level and started the development process of the new generation of flotation cells. The volume of the 600 Series SuperCells™ varies from 600 to 660m<sup>3</sup>, depending on launder configuration (600m<sup>3</sup> with inside launders, 660m<sup>3</sup> with outside launders). The 600 Series SuperCells™ will use array of newly developed FLSmidth mechanisms: self-aspirated WEMCO® with Vortex Stabilizer™ and the whole range of newly developed Dorr-Oliver® forced air mechanisms designed to float wide range of particle sizes. Hydrodynamic and metallurgical response of all these mechanisms will be tested during the evaluation period. To design the enormous SuperCells™, FLSmidth made CFD models of existing cells and scaled them up using dimensionless and hydrodynamic analysis. Results of the hydrodynamic testing of the forced air mechanisms will be presented.

**9:39 AM**

## **Froth Miner Industrial Testing**

*K. Caldwell and T. Sok; Research and Development, FLSmidth, Midvale, UT*

A new piece of equipment to increase froth recovery from flotation machines has been developed by FLSmidth and has been tested and proven to increase the recovery in industrial applications. As the final stage of product development, an industrial prototype of the Froth Miner was produced and installed in an industrial copper operation. The principal behind the Froth Miner is to actively recover froth from a flotation cell, with the ability to do this at select locations within the froth. The Froth Miner is an automated system that tracks the slurry level in the cell to maintain a desired offset of the suction heads. The purpose of the testing was to validate the principal of the Froth Miner as well as continuously run a unit onsite to determine the industrial reliability of the machine. The results from the metallurgical testing showed improvements in both the copper and moly recovery when the Froth Miner was running. The Froth Miner also proved that with a few minor upgrades the unit is ready for industrial application and it will fit a wide range of cell applications and production sizes.

9:56 AM

## **Using Pico and Nano Bubbles For Coarser Particle Size OF Dolomitic Phosphate Reverse Column Flotation**

*F. Peng<sup>1</sup> and Y. Xiong<sup>2</sup>; <sup>1</sup>Mining Engineering, West Virginia University, Morgantown, WV and <sup>2</sup>Mining Engineering, West Virginia University, Morgantown, WV*

A laboratory-scale 50 cm diam phosphate reverse column flotation study (float MgO rich and depress the phosphate rich particles) for low grade dolomitic phosphate ore from Florida, revealed that, the collecting ability of tiny air bubbles and solid particles, but also the selectivity of dolomite flotation have been improved significantly. Both P<sub>2</sub>O<sub>5</sub> grade and P<sub>2</sub>O<sub>5</sub> recovery are greatly enhanced in the presence of pico and nano tiny bubbles. In this presentation, the dolomitic phosphate reverse column flotation using pico and-nano bubbles, which is capable of extending to float ultrafines of minus 75 micron particle size and coarser size fractions of -700+300 micron particle size ranges, will be demonstrated and discussed. The keys operating parameters include collector such as CF413B fatty acid, and frother MIBC dosages, feed solid concentration, feed rate, air flowrate, and pH, will also be presented and discussed based on the Design of Experiment analysis results.

10:13 AM

## **Polymeric Depressants as Safer and Efficient Alternatives to NaSH in Cu-Mo Separations: The Role of Mineralogy and Flotation Gas**

*E. Arinaitwe and D. Nagaraj; Cytex Industries Inc., Stamford, CT*

In Cu-Mo separations, copper sulfides and pyrite are depressed using inorganic reagents such as NaSH while floating molybdenite selectively. NaSH and related reagents have potential hazards in terms of safety, health, storage and transportation. The wide variability in composition and mineralogy of Cu-Mo concentrates often results in large swings in performance and demands high depressant dosages. Many plants use nitrogen (instead of air) to reduce NaSH consumption, but this does not eliminate the hazards. We have demonstrated that the polymeric modifier AERO<sup>®</sup> 7260HFP has the potential to replace up to 90% of the inorganic depressants while providing the required metallurgical performance and improving the SHE profile of the operations. In this study, detailed mineralogical and flotation studies conducted on diverse Cu-Mo bulk concentrates revealed that AERO<sup>®</sup> 7260HFP is quite effective and versatile in selective separation of Cu-Mo concentrates including those containing secondary Cu sulfide minerals, and in both air and N<sub>2</sub> systems. Compared to NaSH, the polymeric depressant provides better performance/dosage ratios and is less sensitive to changes in feed grade and mineralogy.

10:30 AM

## Designing and Optimizing Flotation Circuits from Mineral Liberation

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

A first-principle flotation model has been developed based on the premise that the kinetic energy barrier for bubble-particle attachment can be reduced by the hydrophobic force, which varies with particle contact angles. In the present work, the mineral liberation data reported by Welsby et. al. (Minerals Eng., 97, 59, 2010) have been used to determine the size-by-class contact angles that can be used to predict the size-by-class flotation rate constants. The model predictions are in excellent agreements with the pilot-scale flotation test results obtained by Welsby et al. The model may be useful for designing and optimizing flotation circuits from liberation data.

10:47 AM

## Solid-Liquid Mixing and Suspension Studies in Flotation Cells

*M. Basavarajappa and S. Miskovic; Metallurgical Engineering, University of Utah, Salt Lake City, UT*

Numerical simulations of moderately-dense to dense suspension flows are carried out in lab-scale flotation cells. Computational Fluid Dynamics (CFD) models are being increasingly used to predict and understand the behavior of dispersed phase in complex geometries since obtaining meaningful measurements in such systems is very laborious and expensive. To this end, effects of various modeling approaches and geometrical variations on mixing and suspension behavior inside a flotation cell are investigated. Eulerian-Eulerian approach is used to model the dynamics of continuous and discrete phase. Different drag models are compared for particle sizes frequently encountered in flotation applications leading to better understanding of inter-phase interactions. Effect of impeller blade design, solids loading, impeller size and clearance are additionally investigated. Mixing efficiency is evaluated based on the different approaches proposed in the literature for stirred tanks and critical discussion on their suitability to flotation cells is presented.

11:04 AM

## Improvement in Hematite Flotation with a Novel Iron Depressant

*X. Yin, J. Maki, S. Kofsky Wofford, L. Moore, M. Costa and T. Resende; Kemira Chemicals, Atlanta, GA*

Cationic reverse flotation is widely used to concentrate iron. Continuing depletion of high grade ore as well as the increased iron demand has led to the need for improvement on flotation. Starch is commonly used to depress iron during flotation, however, as ore quality declines alternate chemistries are needed to increase flotation selectivity. Kemira has developed a new synthetic iron depressant, Kemira E-4931, which is able to improve the iron recovery without sacrificing the iron grade. In this study, the performance of E-4931 was evaluated using a hematite iron ore sample. The effects of depressant dose, collector dose, frother dose, and pH were investigated using a design of experiment (DOE) methodology. E-4931 demonstrated a signifi-

cant increase in iron recovery while maintaining the iron grade. The potential use of this new depressant in industrial setting will be discussed.

## **Mineral & Metallurgical Processing: Separation: Pyrometallurgy**

**9:00 AM • Wednesday, February 18 • 712**

*Chair: U. Srivastava, Midrex, Pineville, NC*

**9:00 AM**

### **Introductions**

**9:05 AM**

### **Pyrometallurgy of High Arsenic Copper Concentrates**

*P. Taylor; Metallurgical and Materials Engineering, Kroll Institute for Extractive Metallurgy, Colorado, CO*

Various methods to treat high arsenic copper concentrates through pyrometallurgical processing are presented. Examples are drawn from various past and current operations and research. Some of the methods discussed include: controlled oxidation roasting, adaptation of some smelter technology to accept higher amounts of arsenic, complete oxidation with arsenic fixation; sulfation roasting; acid baking, soda ash roasting, and others methods. Other topics include: a short discussion of other antimony and bismuth impurities; the effects of arsenic on copper electro-refining and product purity; and methods for the ultimate disposal, or marketing, of the arsenic. Work being done at the Colorado School of Mines is also presented.

**9:25 AM**

### **High Efficiency Copper Extraction Through Slag Input in Copper Pyrometallurgy Processes**

*R. Reddy, M. Zhang, V. Nikam and P. George; Met. Matls. Eng., The University of Alabama, Tuscaloosa, AL*

The efficiency of copper recovery by different input routes of copper slag that are used in copper extraction with  $\text{CuFeS}_2$  as the input material is studied and compared with conventional copper smelting processes. Heat and material balance calculations were carried out to find the energy required, oxygen consumed for each step and the amount of Cu that will be produced. The amount of  $\text{SO}_2$  gas that will be produced in each step was also calculated. Bornite ( $\text{Cu}_5\text{FeS}_4$ ) as the copper feed was also calculated. It was found that the approach II (Converting and smelting slags input to slag cleaning unit) gives higher Cu recovery. Approach I (Converting slag input to smelting and smelting slag input to slag cleaning) was found to produce lower  $\text{SO}_2$  emissions. It was also found that approach

It gives higher Cu recovery than approach I. Because of higher copper recovery, approach II is preferred for copper extraction process.

**9:45 AM**

15-118

## **Improving the Performance of Stainless Steel Castings Used in a Cyclical Temperature Environment**

*J. Panchar; Engineering, Pennsylvania State University, Coal Township, PA*

Stainless steel castings are used in abundance in the mineral processing industry. In rotary kiln based processes, these castings are typically exposed to high loads, corrosive elements, mechanical abrasion and cyclical temperature exposure. In the processing of iron ore pellets, it is typical to preheat the pellets before passing them into a rotary kiln for final heat-hardening. The expected life of the castings used in this preheater can be quite short, their cost quite high and the effort to replace them very labor intensive. The goal of this study was to gain an understanding of the failure mode of these castings. With that basic understanding, modifications to the alloy content could be made to achieve a new operational paradigm. That paradigm could be a cheaper casting, a longer lasting casting or a casting tailored to special operating conditions (for example, highly corrosive gases or sudden temperature shocks).

**10:05 AM**

## **Where to Invest, the Horse or the Wagon: Answer – Both may be Needed to Make Alternative Iron Processes Viable**

*L. Southwick; L.M. Southwick & Associates, Cincinnati, OH*

Interest is increasing in the production of high quality iron units, especially from ore, suitable for direct feed into the EAF melt shop. These “virgin” iron units allow the production of higher quality steels, which can compete in manufacturing areas that heretofore have mostly been the territory of blast furnace and BOF steel. With suitable quality iron, a gas based DRI plant will produce the needed purity. But what if coal must be used as reductant, or only low quality iron ore is available, or waste iron oxides are to be processed, all with attendant low iron concentrations, impurities and substantial slag forming components? The single unit alternative iron processes that have been attempted so far cannot be considered commercial successes. It seems as though these processes need either a front end pre-reduction step, or a back end reduction completion, melting and slag separation step. Several examples of such combinations of processes will be evaluated operationally, economically and technically, and their positives and negatives discussed to help clarify the options available.

10:25 AM

## Advancement in Midrex DR Process

*G. Hughes and U. Srivastava; Research and Development, Midrex Technologies, Pineville, NC*

Since the first Midrex DR plant was installed in 1969, there have been several improvements made to the Midrex DR Shaft furnace process. These improvements were made to meet the current iron and steelmaking industry standards. Initially, the Midrex DR process was only able to produce cold directly reduced iron (DRI) at a discharge temperature below 50°C. Now the Midrex DR process can produce hot DRI at discharge temperature between 650 – 700°C. The hot DRI can be directly discharged to an Electric Arc Furnace (EAF) for steelmaking. Discharging hot DRI to an EAF can save approximately 140 – 150 kWh per ton of DRI. Currently, multiple discharge combinations of hot DRI, hot briquetted iron (HBI) and cold DRI are available. Where natural gas prices are high, the Midrex DR process can also utilize reducing gas produced from coal gasification and coke oven gas. With continuous improvement in the Midrex DR process, the Midrex shaft furnace process has maintained the ability to produce high quality metallized DRI with low energy consumption.

10:45 AM

15-136

## Utility of Mass-Balanced EH-pH Diagrams II: Stoichiometry of Cu-As-S-H<sub>2</sub>O System

*R. Gow<sup>2</sup>, H. Huang<sup>1</sup> and C. Young<sup>1</sup>; <sup>1</sup>Metallurgical & Materials Engineering, MT Tech, Butte, MT and <sup>2</sup>FLSmidth Dawson Labs, FLSmidth, Midvale, UT*

Previously, Gibbs' phase rule was applied to mass-balanced EH-pH diagrams for the Cu-As-S-H<sub>2</sub>O system. Diagrams were generated using the stoichiometry of enargite as a basis. In this study, the calculations were expanded to cover the stoichiometries of three other Cu-As-S minerals (tennantite, sinnerite, and lautite) and compared to enargite. Stability regions within the resulting EH-pH diagrams were found to change with stoichiometry such that a particular mineral would predominate if its stoichiometry was used in the calculation. Solution speciation was also found to vary, with thioarsenate being the best example. This stoichiometric effect helps to explain results reported in the literature and would be difficult to realize if it were not for mass-balanced calculations.

## Mineral & Metallurgical Processing: Student Poster Session

9:00 AM • Wednesday, February 18 • 708

*Chairs: L. Schlink, Freeport- McMoRan Copper & Gold, Oro Valley, AZ*

*E. Sarver, Virginia Tech, Blacksburg, VA*

This session will highlight mineral and metallurgical processing research conducted by undergraduate and graduate students. The session will feature oral presentations followed by a poster session at the MPD luncheon.

## Mining & Exploration: Geology: Mineral Resource Estimation

9:00 AM • Wednesday, February 18 • 707

Chair: **Z. Black**, 3L Resources, Ltd, Lakewood, CO

9:00 AM

### Introductions

9:05 AM

15-124

### Representative Sampling

*B. Stone; Geology, Roscoe Postle Associates USA Ltd, Lakewood, CO*

An orebody is a mixture of minerals in proportions that vary in different parts of the mass. As a consequence the proportion of contained metals also varies from place to place. Therefore, a single sample taken in any particular place would not contain the same proportion of metals as does the orebody as a whole except by a highly improbable coincidence. (Baxter and Parks, 1939) What is the impact on property economics if it was characterized with properly conducted representative sampling? Isn't knowing this at the earliest stages of evaluation better? What is the nature of the ore containing host rock? What is the mining engineer's perspective? What is the processing perspective? What about the geotechnical perspective? The author has chosen five deposits with which he has personal experience to illustrate the nature and requirements of representative sampling: 1. The porphyry copper experience at Yerington, Nevada 2. The skarn mineralization at Bingham Canyon, Utah 3. The fluorite deposits in the Kerio Valley, Kenya 4. The oil sands in Northern Alberta 5. The lead-zinc-copper-precious metals massive sulfides in Bathurst, New Brunswick.

9:25 AM

15-101

### Wireframe Construction in Resource Estimation: Methods and Practices

*K. Zabrusky; Gustavson Associates, Lakewood, CO*

Wireframe construction is an integral part of resource estimation. Wireframes control domaining of samples and data for geostatistical analysis and grade estimation. They may also provide 3D representations of lithology and grade domains. Thus, the way in which a wireframe is constructed has implications throughout the resource estimation process. Proper construction technique and understanding of wireframing processes should be a high priority in a model workflow. Herein is presented an overview of two main categories of wireframes: implicit and explicit. Construction differences between these two types are highlighted. Factors affecting the choice between the two wireframe types will be discussed, including data quantity, data distribution, and sampling technique. Deposit geometry

also plays an important part in wireframe construction. The role of geologic knowledge, cross section orientation, and deposit type in regards to wireframe construction will be discussed. The effect of wireframe type on resource estimation will be examined. Finally, best practices for creating meaningful solids that contribute to a reasonable grade estimation are outlined.

**9:45 AM**

## **A Practical Discussion of the Use of Unfolding Techniques in Block Modeling to Address Multiple Related Structures that Influence Mineralization**

*R. Cooper; Newmont Mining, Colorado Springs, CO*

The techniques used to unfold estimation routines are well known. Generally these use either a changing orientation of the search ellipse or the ellipse itself may be complexly deformed to follow a geological or geochemical feature. In either case the input data required for the localized orientation of the primary mineralization may also provide the basis for producing other orientations that may be of interest. For example, the orientation of mineralization from Riedel (R) shears and other dilatant secondary structures can be deduced from the orientation of the primary structures. As the primary structure rotates, so can the orientation of secondary structures change. The discussion will cover the process of using this approach to estimation and pitfalls that may be encountered during the process.

**10:05 AM**

## **Unfolding Techniques to Improve Estimation**

*D. Araujo<sup>1</sup> and Z. Black<sup>2</sup>; <sup>1</sup>3L Resources, Ltd, Lakewood, CO and <sup>2</sup>Datamine, Littleton, CO*

Unfolding techniques have been developed in order to enhance the grade estimation for a Mineral Resources Evaluation. The concept is to transform a given folded orebody into an unfolded coordinate system. However, this practice has not been widely applied in the geologic modeling for Mineral resources estimation due to the difficult and time consuming techniques available. Presented herein is an example of the unfolding method, implemented using a more automated and user friendly procedure. The example being presented demonstrates how to unfold multiple stratified geologic units with structural folds and faults using Datamine Studio®. The Studio unfolding tool transforms the folded geologic shapes into an unfolded coordinate system (UCS). The coordinates defined as, A (across strike), B (down dip), and C (along strike), are calculated based on the linking of hexahedrons between the modeled hanging wall and footwall points of the stratigraphy. The resulting unfolded coordinate system better defines the true distance between sample points and aligns the proper geologic samples improving the variogram, the search volume, and the estimation.

**10:25 AM**

15-110

## **Artifact Reduced Localization of Uncertainty – Lipstick on a Pig**

*E. Daniels, J. Boisvert and C. Deutsch; Mining Engineering - Geostatistics, University of Alberta, Edmonton, AB, Canada*

Estimating the resources of a mineral deposit for long range mine planning is an important challenge. Localization of uncertainty has received significant attention of late. The uncertainty that is localized could arise from indicator kriging, multiGaussian kriging, uniform conditioning, simulation or other means. The process of localizing a model of uncertainty to a single SMU scale block model is appealing. Localizing each panel scale distribution independently yields discontinuities at panel boundaries. These obvious artifacts in the presence of large scale trends are unsightly and unavoidable. Artifacts are reduced by post processing localization results with an optimization approach where artifacts including edge effects are penalized. The methodology and case study presented focus on localizing a set of simulated realizations and reducing the obvious artifacts; however, there are significant problems with localization. These problems include poor local precision and unfulfilled promises with respect to the use of uncertainty. These problems are explained and the best practice of transferring uncertainty through resource assessment and mine planning is discussed.

**10:45 AM**

15-113

## **Dilution and Ore loss Projections: Strategies and Considerations**

*T. Matthews; Geology, Gustavson Associates, Lakewood, CO*

One critical factor in reserves reporting, as well as mine-reserves reconciliation, is a consideration of the impact of dilution and ore loss in the mining process. This paper considers the implications of various factors on dilution and ore loss projections, including orebody geometry, mining method, and ore control systems. We also discuss the implications of resource estimation methodology on dilution considerations for reserves.

**11:05 AM**

## **Optimum Dig Line Design for Open Pit Grade Control**

*E. Isaaks; Sole Proprietor, Isaaks & Co., Emerald Hills, CA*

Dig line design for open pit grade control is more often than not a manual exercise in contouring ore control model (OCM) block grades. However, optimum contours or dig line polygon designs are generally not obvious where “optimum” means maximizing profit by minimizing the misclassification of individual OCM blocks within a dig line polygon constrained by a minimum mining width. In fact, a significant number of calculations involving metal prices, block grades, process recovery rates, cutoff grades, and break even costs are actually required to design optimum dig line polygons. Thus, optimum or maximum profit dig line designs constrained by a minimum mining width are

generally accomplished only with the aid of computer software. The task is far too laborious for manual dig line design. Indeed, experience shows computer generated dig line designs generally increase net revenue by 2% to 5% over manual designs. An algorithm for the design of optimum dig lines constrained by a minimum mining width is presented in the paper together with several examples from current mining operations.

## **Mining & Exploration: Management: MSHA**

**9:00 AM • Wednesday, February 18 • 705**

*Chair: S. Anderson, Hogan Lovells US LLC, Denver, CO*

**9:00 AM**

### **Introductions**

**9:05 AM**

### **Mine Safety and Health — Policy, Science, Enforcement and Training on a Global Scale**

*S. Anderson and L. Titus; Hogan Lovells US LLP, Denver, CO*

This paper will address updates on developments under MSHA in the United States over the past year. Discussion will be held regarding the respirable dust rule, the refuge rule, and similar regulatory developments. We will also discuss enforcement trends and how to deal with MSHA in a stricter regulatory environment.

**9:25 AM**

### **Mine Safety and Health — Policy, Science, Enforcement and Training on a Global Scale**

*W. York-Feirn; Colorado Division of Reclamation, Mining and Safety, Denver, CO*

The paper will address the training involved in the State of Colorado for the mine safety program highlighting what works and what doesn't when training for safety. Discussion will be held regarding the best practices available for mining companies when setting up their safety programs.

**9:45 AM**

### **Mine Safety and Health — Policy, Science, Enforcement, and Training on a Global Scale**

*S. Anderson<sup>1</sup>, M. Jewell<sup>2</sup>, L. Moore<sup>4</sup>, W. York-Feirn<sup>3</sup> and L. Titus<sup>1</sup>; <sup>1</sup>Hogan Lovells, Denver, CO; <sup>2</sup>Burns Figa Will, Denver, CO; <sup>3</sup>Division of Reclamation Health and Safety, Denver, CO and <sup>4</sup>Hogan Lovells, London, United Kingdom*

This paper will address (i) recent regulatory changes implemented by MSHA in the US, (ii) enforcement trends for MSHA in the US, (iii) the use of public health science as the basis for

mine health and safety policy, (iv) latest techniques in training for mine health and safety, and (v) and overview of international standards for mine and health and safety.

**10:05 AM**

## **Mine Safety and Health – Policy, Science, Enforcement, and Training on a Global Scale**

*L. Moore; Hogan Lovells International LLP, London, United Kingdom*

This paper will address the evolving mining safety standard for international companies, as well as the way in which international companies are held to international best practices above and beyond those applicable in a host company. Discussion will be held regarding corporate social responsibility as a method of creating new legal requirements for international operations.

**10:25 AM**

## **Evaluation of the Predictive Capabilities of MSHA Inspection Results and Organizational Characteristics via Machine Learning Classification Models**

*J. Germand; Energy and Mineral Engineering, Penn State University, University Park, PA*

Regulators and mining companies have an interest in understanding where the next serious worker injury or fatality is more likely to occur. While expert-designed ranking systems reliant on MSHA data such as the Safe Performance Index (SPI) appear to have some predictive power in anticipating fatalities, these systems have limitations as a management tool beyond serving as an alert. To test the theoretical extent that MSHA data could be used to predict safety incidents in mines, this study employs non-linear, unsupervised, machine learning classification models that subdivide mines into groups on the basis of their incident rates in an automated fashion without the biases of any experts. The attributes of each automatically revealed subdivision, such as mine, staff, and organizational characteristics are contrasted through the positive deviance approach to consider what types of changes may make the course of a more risky mine more similar to that of the safer mines. These models show that MSHA and organization data can predict 88% of the variance in severity-adjusted incident rates between mines.

## **Mining & Exploration: Operations: Innovations in Open Pit Mining Operations**

**9:00 AM • Wednesday, February 18 • 706**

*Chair: S. Newman, Barrick, Layton, UT*

*Sponsored by: MWH Global*

9:00 AM

## Introductions

9:05 AM

## Reducing Costs Through Innovative Waste Dump Optimization

*M. Russell and N. Journet; Landform Solutions, Subiaco, WA, Australia*

Pit optimization tools have been in existence since the 1980's and nowadays no mine is developed without first undertaking a rigorous optimisation study and risk assessment. However, the same cannot be claimed for the design of waste dumps and low grade stockpiles. Often these are simply manual designs fitted into a convenient location on the side of a pit, with limited economic or environmental considerations. Waste dumps offer great potential for improving the overall economic and environmental outcomes of a mining operation. Studies have shown that rigorous optimization of all physical and economic parameter and spatial constraints can significantly improve safety, reduce the mining cost and truck operating hours, increase truck productivity, reduce greenhouse gas emissions, improve environmental outcomes and reduce closeout costs. Economic and environmental outcomes can be mutually inclusive with a complete and rigorous optimization process.

9:25 AM

## Independent Review After the Manefay – Kennecott's Mine Technical Review Team

*B. Ross; Rio Tinto Kennecott Utah Copper, Salt Lake City, UT*

After the world's largest high wall failure in 2103, Kennecott Utah Copper was faced with the huge task of safely remediating the effects of the slide to return to normal operations. Because of the scale, unique nature, and uncertainties of much of the work; a multidisciplinary team of independent and Rio Tinto experts were assemble. This Team reviewed geotechnical monitoring, analysis and operating methodology to ensure procedures were implemented to keep people safe and work could be completed effectively. This team, called the Mine Technical Review Team (MTRT), included geotechnical, hydrological and mining experts. Utilization of the MTRT is one of the reasons that the remediation work was successful in delivering the remediation safely and in a timely manner. Even though the critical remediation was completed in November of 2013, Kennecott has continued to utilize the MTRT to review critical geotechnical analysis, dewatering, and mine plans because of the benefits the company receives from their independent review and expertise. This paper discusses the charter the team works under, the membership of the team as well examples of some of the issues that the team reviews.

**9:45 AM**

## **Tailings capacity, an Unusual Ore Reserves Constraint**

*J. VanOs; pvdc mine, Barrick Gold, Cabarete, Dominican Republic*

The cost of construction of tails facilities at Pueblo Viejo Mine in the Dominican Republic is a major sensitivity in the project's economics. All ore tails and potential acid rock waste are sent to the facility, and as the density of these two material types vary greatly a change in the economic cutoff or pit design requires a different tails capacity. Ore reserve estimations at PVDC are an iterative process, whereby the size and costs of different tails facilities are evaluated against different pit sizes and ore cutoffs. The current Pueblo Viejo reserves have been reported at an elevated cutoff (using \$1000/oz Au price base) as a result of economic evaluations of various potential reserve scenarios.

**10:05 AM**

## **Blast Improvement at the Betze-Post Open Pit: Techniques and Strategies**

*M. Ransom and B. McKnight; Goldstrike Open Pit Engineering, Barrick Gold of North America, Elko, NV*

A blast improvement program is in-progress at the Betze-Post open pit to review the blasting practices and to determine what improvements can be made. It was identified that data was being collected from multiple sources, but was not in an easily accessible format and, thus, was not effectively utilized in blast pattern design or during the blasting process. The type of data collected includes: pre/post blast assessments, geotechnical data, geological mapping data, shovel dig rates and drill penetration rates. A primary goal was to get this information in an agreed upon format so that it could be used for blast pattern design, load modification and mining performance analysis. Along with the existing types of data being collected, two other areas were identified where data was needed and they include batter performance and fragmentation. New data collection methods, such as LIDAR, Perfect Dig software and photogrammetry, are being examined to help determine the most effective and efficient ways to obtain data for batter performance and fragmentation. Data collection techniques, results to-date, additional areas of improvement and the future goals of this program will be discussed.

**10:25 AM**

## **ROI on Proactive Fatigue Management – Is the Investment Worth It?**

*I. Tandoh<sup>2</sup>, D. Flores<sup>1</sup> and E. Smidt<sup>1</sup>; <sup>1</sup>Project Engineering, Guardvant Inc., Tucson, AZ and <sup>2</sup>Operations, Goldfields Ghana Ltd. (Tarkwa Mine), Accra, Ghana*

Studies have shown that fatigue causes approximately 60%-70% of mining accidents involving haul trucks. Mines understand the importance of investing in operator fatigue monitoring from a health and safety perspective, and are also now realizing the high potential ROI, and rapid financial payback. Implementing an effective fatigue management program requires a significant

investment. Because of this, mining companies want to quantify both the safety and financial benefits that the technology can provide. In this study, we share how a large open pit operation, Gold Fields Tarkwa Mine, realized substantial cost savings by implementing a proactive fatigue management program across their entire fleet of haul trucks. We analyzed three years of fatigue related accidents prior to implementation of the program, and one year after the program was implemented. The analysis includes detailed direct equipment repair cost data, as well as estimated indirect costs caused by production and time loss. The study shows that the mine realized impressive cost savings immediately after the program was implemented, primarily due to a dramatic decrease in fatigue related accidents.

**10:45 AM**

## **Modeling Full-Scale Blast Heave with 3D Distinct Elements and Parallel Processing**

*D. Preece<sup>1</sup>, A. Tawadrous<sup>1</sup> and S. Silling<sup>2</sup>; <sup>1</sup>Blasting Applications Americas/EMEA, Orica Mining Services, Bluffdale, UT and <sup>2</sup>Sandia National Laboratories, Albuquerque, NM*

The two key results of rock blasting are fragmentation and movement of geomaterials. Movement/flow of the material is often referred to as heave. Blast-induced heave can be utilized to make mining more efficient since it is more efficient to move rock with explosives than with mechanical equipment. Such is the case with coal mine cast blasting. Understanding and prediction of heave is especially important for surface mineral blasting due to the resulting movement and mixing of ore and waste. Computer programs for predicting 2D blasting-induced heave have been used in mining for decades. The past few years have seen the advent of 3D distinct element modeling of heave. Most blasting situations are three-dimensional in nature and, thus, require a 3D modeling approach. This paper documents the first full-scale blasting simulations in 3D with distinct element models that include hundreds of blastholes and millions of particles, made possible with parallel processing. Surface mineral blasting is the focus of this study which treats the effect of blasthole delay timing on ore waste and dilution. This new computational capability will help increase ore recovery in mineral mining.

## **Mining & Exploration: Operations: Underground Mine Ventilation**

**9:00 AM • Wednesday, February 18 • 704**

*Chair: K. Gardner, Newmont, Elko, NV*

**9:00 AM**

## **Introductions**

9:05 AM

## **“Reaching for the Bottom” – Newmont’s Leeville Turf No. 3 Ventilation Shaft: Sinking Through Frozen Ground**

*J. Taylor; Amec Foster Wheeler plc, Mesa, AZ*

Amec Foster Wheeler plc is currently executing an EPC contract with Newmont Mining Corporation and Thyssen Mining on sinking a new 26 ft. diameter ventilation shaft to a total depth of 2,050 ft at Newmont’s Leeville underground operation located north of Carlin, NV. The project highlights include freezing the associated ground in order to sink through the water table. This is the first application of this type ever executed in the State of Nevada.

9:25 AM

## **Design and Implementation of an Automated Ventilation System for Henderson Mine’s 7065 Haulage Level**

*D. Loring, R. Brokering, B. Dhyne and A. Rogers; Climax Molybdenum Co., Empire, CO*

Climax Molybdenum Company’s Henderson Mine, owned by Freeport McMoRan Inc., is a 33,000 tonne per day panel caving molybdenum mine located about 69 km west of Denver, Colorado. As the footprint of the mine expands, with production coming from multiple panels on two separate levels of the mine, the efficient and effective use of air becomes essential in order to maintain or reduce ventilation energy costs. The underground mining industry has been slowly moving towards automated ventilation systems, commonly known as “ventilation on demand”, and Henderson is no exception. Henderson Mine successfully commissioned the first level-wide automated ventilation system in the mine on the 7065 truck haulage level. This paper describes both the former system consisting of individual fanned chute exhaust raises and the current automated system utilizing louvers controlled via the PLC system. It will also discuss the improvements in air quality and relative cost savings that have been and will be recognized as the haulage level continues to expand.

9:45 AM

## **Case Study: Main Fan Selection - Moving the fan from underground to surface**

*A. Rai; Barrick Turquoise Ridge Inc, Winnemucca, NV*

The current main fan is underground with physical operating points, and prices in order to maintain the appropriate drift size dedicated ventilation drift. The paper will discuss the approximate fan sizes, operating points, and models were determined mitigating re-circulation use of bulkheads around the intake and exhaust shaft, and leakage by moving the fan on surface . The paper will cover technical fan selection process, operations commissioning and explain benefits on total cost of ownership of moving the main fan to surface.

10:05 AM

## **A New Mine Ventilation Network Model Calibration Algorithm**

*G. Danko and D. Bahrami; Mining Engineering, University of Nevada, Reno, Reno, NV*

All ventilation models used for mine safety, health, and cost benefit analyses and optimization must be calibrated for correctness. A new procedure and a numerical optimization algorithm is explored for robustness and convergence of calibration of the ventilation model against measurement results. The calibration algorithm employs relative sensitivities of individual measurement results to individual branch resistances. The mine ventilation model provides balanced and inter-connected results for the entire network, allowing to determine the most significant groups of measurement data and unknown branch resistances which can be utilized for robust model calibration. The algorithm omits insensitive branches from the procedure improving the quality of match between simulation and measurement results in a least-square-fit sense. Albeit the reduction of the number of air branches by elimination is computational intensive, it is advantageous for reducing real time and cost of mine ventilation surveys in addition to increase robustness of the automatic calibration procedure. The new algorithm makes the method a viable tool for industrial applications.

10:25 AM

15-133

## **Optimization of Costs for Trackless Mining Ventilation and Cooling Systems**

*P. Rostami<sup>1</sup> and C. Rawlins<sup>2</sup>; <sup>1</sup>Mining, Stantec Consulting Inc., Tempe, AZ and <sup>2</sup>Rawlins Mining Engineers, Oakville, ON, Canada*

Ventilation systems are not only an integral part of any underground mine design but are a significant contributor to the mine's capital and operating costs. The ventilation and cooling design systems presented in this paper were part of the prefeasibility evaluation of an underground platinum mine in South Africa. The mine would ultimately operate at the depth of 1,200 m below surface with a proposed 4 Mtpa production rate. The proposed mining operation is a highly mechanized operation using diesel equipment. Significant daily production rate, large amount of equipment and dynamic nature of the operation, contributed to a challenging while flexible ventilation design requirements. This paper presents how to safely and efficiently optimize capital expenditure and operating costs associated with the mine air cooling and refrigeration system through practical ventilation design practices. Successful capital and operational savings by modulating installation and commissioning of refrigeration facilities can influence the economic realization of such systems. The adapted planning and design approach provided a cost-effective advantage while complying with design safety and regulations.

10:45 AM

15-027

## Effect of CO<sub>2</sub> on the Human Body

*H. Mischo and J. Weyer; Mining Engineering, Technical University Bergakademie Freiberg, Freiberg, Germany*

On 01 October 2013 one of the biggest CO<sub>2</sub> outburst in the history of potash mining appeared in the mine Unterbreizbach, Germany. A couple of years ago 107 people have been injured by outstreaming CO<sub>2</sub> from a fire extinguishing unit. Every year accidents in wine cellars, silos, wells and waste water lines resulting from CO<sub>2</sub> are published in the newspaper or TV. Even today wrong comments, wrong conclusions and wrong advices are given or can be found in papers, books and the internet. The real effect of CO<sub>2</sub> on the human body is commonly unknown by the public. Furthermore even rescue teams often do not know the real effect of CO<sub>2</sub> on the human body and how CO<sub>2</sub> can influence the selection of rescue equipment. The paper discusses some wrong or misleading statements. It also clarifies the term "suffocation" in regard with CO<sub>2</sub> and explains what real happens if the human body is exposed to CO<sub>2</sub>. Furthermore some other problems during rescue operations are mentioned.

11:05 AM

## Ventilation Drift Sequencing to Manage Capital and Operating Cost for Very-large Scale Underground Mining Projects

*I. Loomis<sup>1</sup>, M. Ramirez<sup>1</sup> and A. Tarigan<sup>2</sup>; <sup>1</sup>Mining and Metals, AMEC, Denver, CO and <sup>2</sup>Mining and Metals, AMEC, Vancouver, BC, Canada*

During the development and ramp-up phases of very-large scale mining operations there is significant capital invested years before the mine begins production. This coupling of the initial development and production ramp-up can afford the mine an opportunity to sequence the development of primary ventilation drifts to coincide with the airflow demands of the development through full-scale production. The advantages that can be gained by deferring parallel drift development to manage the rate of capital spend relative to the variations in operating cost have been discussed by the authors in a previous paper. This study continues the evaluation as the cost model is advanced to reflect the advantages of multi-heading development and variations in advance rates. The outcomes of this study show the potential advantages of deferring capital and the associated risks if the primary ventilation drift infrastructure is permitted to fall behind the project critical path.

## Mining & Exploration: Technology: New Design Concepts and Technologies in Mine Ventilation

9:00 AM • Wednesday, February 18 • 703

*Chairs: K. Kocsis<sup>1</sup>, University of Nevada, Reno, Reno, NV  
H. Dougherty<sup>2</sup>, Virginia Tech, Newport, VA*

9:00 AM

## Introductions

9:05 AM

### **Optical Fiber Based Air Properties Measurement for Distributed Sensing in Underground Mines**

*M. Momayez and C. Cantero; Mining and Geological Engineering, University of Arizona, Tucson, AZ*

Abstract: Various systems for measuring air properties using optical fiber sensors are presented. A single optical fiber allows for distributed sensing throughout a mine and carrying communication signals. In one case study, we evaluate the performance of a hot-wire anemometer based on Brillouin optical time-domain analysis. Air speeds from 0 m/s to 10 m/s and dry-bulb temperatures between 15 °C and 25 °C are examined. In another study, the fiber loop ringdown technique commonly used for high-sensitivity and fast response measurement of physical properties is used to determine the range and resolution limit of high air and gas flows (10 liters per minute). Advantages and disadvantages of each system are discussed.

9:25 AM

### **Underground Fire Rollback Simulation with High Density 3D Network Analysis**

*C. Stewart; Mining Engineering, University of Queensland, Thornlands, QLD, Australia*

Fire rollback can cause smoke and toxic fumes to move along the roof of tunnels in the opposite direction to normal ventilation flow, creating difficulty in predicting the likely pathways of fumes through the remainder of the ventilation system. This has serious safety implications in understanding what parts of a mine may be affected by fire. Modelling rollback behavior locally is possible with computational fluid dynamics methods(CFD) but is not practical for mine wide simulation due to size and time constraints. Empirical prediction that considers size and slope of airways can also be used, however this integrates poorly into a simulation model.. This proposed method builds a high density three-dimensional mesh of pathways within the main ventilation airways around a fire. This allows a transient mass balanced Hardy Cross method to move the air currents independently within the defined airway volume, based on heat and natural buoyancy of each pathway . This paper explores whether the method provides reasonable results and can be fully integrated into normal network analysis to allow high speed mine wide simulation without the complexity of CFD analysis or empirical assumptions.

9:45 AM

## **Early Warning System Design for Accident Prevention with Ventilation Monitoring and Evaluation**

*W. Asante, D. Bahrami and G. Danko; Mining Engineering, University of Nevada, Reno, Reno, NV*

Recognition of hazardous conditions in mines is of prime importance for the safety of mining operations. Mine monitoring has been widely used for this task with increasing success. Retrospective analysis and evaluation of atmospheric parameters is utilized for checking compliance with mine safety regulations. However, changes in the mining and ventilation conditions and parameters may present hazardous transient scenarios that require immediate preventive actions. Current atmospheric monitoring and evaluation practices regarding the ventilation network data are mainly retrospective and lack forecasting evaluation capabilities such as identifying scenarios that may soon lead to an accident. The paper reviews current monitoring data analysis practices for safety and compliance checks. The possibility of adding an Early Warning Predictor (EWP) is discussed for the added goal of recognizing the emergence of safety hazards. The warning signal from the EWP provides an indication of an imminent danger. The system design of the EWP is discussed. The software APPS is being designed and developed for mining applications under the support of the Alpha Foundation.

10:05 AM

## **Ventilation Optimization, Part I**

*C. lu and D. Bahrami; Mining Engineering, University of Nevada, Reno, Reno, NV*

In spite of the high energy cost, there may exist over-ventilation and uneconomic airflow distribution design in underground mines. It is difficult to intuitively reduce ventilation energy cost while maintaining health and safety. The paper reviews the elements of ventilation optimization. The “best practices” should all be exercised first for optimization considering also their broader economic impact. The second step is to consider using booster fans instead of air regulators for air distribution control. Air doors are used for low installation cost to force air through high-resistance network areas. The application of booster fans directly in the high-resistance network areas is cheaper on energy. Numerical examples show major differences in energy cost between air doors and booster fans for air distribution control before considering the added cost of booster fans over air regulators. The third step of ventilation optimization is to achieve the best match between the air flow in the ventilation network and the specified minimum air flow requirement for both safety and health for each air branch. This third step will be presented in Part II of ventilation optimization.

10:25 AM

## **Sparse Calibration of Ventilation Models**

*M. Sunkpal, D. Bahrami and G. Danko; Mining Engineering, University of Nevada, Reno, Reno, NV*

Every modern underground mine needs and uses a ventilation model which can predict airflow conditions in the underground environment. All ventilation models need calibration and verification as well as continuous re-calibration as mines never stop changing with operation. Conducting a ventilation survey in a complex underground mine sometimes with over 2000 air branches is a tedious and economically imprudent activity. This paper reviews and presents a new method, tested with numerical examples, to achieve this task. The method utilizes measured values of pressure and air flow rate from selected few main airways. The essence of the method is a numerical algorithm which matches the in situ mine surveying data of branch pressure differences and air flow rates with the ventilation network model. The algorithm adjusts the air flow resistance in each branch until the differences between measured and simulated values for pressure and air flow rate are minimized in a least-square-fit sense. The results show that the method in its reduced-element form is indeed very efficient in finding the optimum solution for the unknown air branch resistances.

10:45 AM

## **A Review of Heat Stress Indices**

*P. Roghanchi, K. Carpenter and K. Kocsis; Mining Engineering, University of Nevada, Reno, Reno, NV*

As the base and precious metal mines in the US become deeper, more productive and further mechanized, the underground workforce will be exposed to an increasingly hot and humid environment. Hot and humid environments can cause thermal stress, which can seriously affect the performance, overall productivity, safety and health of an individual and can reduce tolerance to other environmental hazards. A heat stress index integrates personal, physiological, and thermal environment parameters into a single number for a quantitative assessment of heat stress. Heat stress indices can be divided into three groups: (1) rational indices, which are based on calculations involving the heat balance equation, (2) empirical indices, based on objective and subjective strain, and (3) direct indices, which involve direct measurements of environmental variables. Each heat stress index has special advantages that make it more suitable for use in a particular environment. This paper aims to review and summarize the existing heat stress indices commonly used for assessing the heat stress conditions in underground mining environments.

## **Mining & Exploration: Technology: Underground Mining Projects & Innovation II**

**9:00 AM • Wednesday, February 18 • 702**

*Chair: A. Nieto, Penn State University, University Park, PA*

**9:00 AM**

### **Introductions**

**9:05 AM**

15-058

### **Empirical Equation for Control of Air Overpressures Produced by Blasting in an Underground Mine**

*N. Rouse and B. Petri; RESPEC, Lexington, KY*

Air overpressure monitoring procedures and instrumentation guidelines which apply to production blasting in underground limestone mining are not readily available. The industry also lacks an applicable source for air overpressure levels that are produced by blasting operations in underground limestone mines. As such, there was no available background data from which the expected overpressure levels from production blasting in a new underground limestone mine could be predicted. During the development phase of the mine, it was imperative that newly constructed underground structures be capable of withstanding the overpressure produced by blasting in nearby production headings. To ensure the structures could withstand the blast-induced overpressure, a study was conducted to record empirical overpressure data and develop a model which could be used to control air overpressure levels by the production crews. This document describes the procedures used to develop the model, the development of the model, and the applicability of the model for predicting underground blast overpressures.

**9:25 AM**

### **Evaluation of DMT Slim Borehole Scanner (SBS) performance in the US underground mines**

*A. Naeimipour<sup>1</sup>, J. Rostami<sup>2</sup> and S. Rapp<sup>3</sup>; <sup>1</sup>Pennsylvania State University, University Park, PA; <sup>2</sup>Pennsylvania State University, University Park, PA and <sup>3</sup>DMT, Essen, Germany*

Borescoping the holes drilled at the roof/ribs of mines is a common practice in underground mines in the US and around the world to gather more detailed geological information and to monitor frequency and characteristics of fractures and joints both natural and those resulted by mining operations. This conventional device, however, offers a limited view of the borehole wall. Slim Borehole Scanner (SBS) manufactured by DMT in Germany is a borehole imaging tool specifically designed for coal mines, which has not been employed in underground mine in the US before. This tool provides an unwrapped 360-degree

image of the borehole, which enables the geologists/engineers to have a better understanding of the rock mass surrounding the borehole. The images of different boreholes can easily be archived for the future reference and for use in various applications. The Pennsylvania State University in collaboration with DMT has performed field tests on SBS in different underground mines. This paper will discuss and evaluate the results obtained from these field tests. Also, advantages and shortcomings of this device in general and in comparison with similar products are briefly explained.

**9:45 AM**

## **Modeling Mining Risk in Room and Pillar Mine Sequencing Using Mixed Integer Linear Programming**

*A. Anani and K. Awuah-Offei; Mining, Missouri University of Science and Technology, Rolla, MO*

A major complexity associated with underground room and pillar (R&P) sequencing stems from the need to manage risk associated with the mining operation. Mixed integer programming (MIP) has been used to solve room and pillar sequencing problems (Sarin et al. 2003 and Schulze et al. 2011). The applications of MIP in room and pillar mine sequencing are still very limited and do not properly account for risk management in mine sequencing. The objective of this study is to incorporate risk management into room and pillar mine sequencing while maximizing the net present value (NPV) of the operation. R&P mine sequencing is modeled as dual-objective mixed integer linear programming problem that maximizes the NPV of the operation and minimizes risk subject to mining constraints. The room and pillar sequence generated resulted in high risk block being mined in later periods, thus risky activity is delayed to allow for time to reduce the risk. Mine engineers can incorporate risk management into mine production sequencing with relatively minimal computational costs.

**10:05 AM**

## **Grasberg Block Cave Pumping System Presentation**

*A. Causey<sup>1</sup>, G. Krug<sup>2</sup> and C. Dipas<sup>2</sup>; <sup>1</sup>Mechanical Engineering, Stantec – Mining, Tempe, AZ and <sup>2</sup>Underground Planning, Freeport-McMoRan Inc., Phoenix, AZ*

PT Freeport Indonesia's proposed Grasberg Block Cave (GBC) Mine is located at an elevation of 3,000 meters in Papua, Indonesia on the west side of the island of New Guinea. GBC is beneath the Grasberg Open Pit and is planned to sustain 160,000 tonnes of ore per day. The caving operation, scheduled to begin in 2017, requires the ability to gravity-drain and capture the expected peak water inflow of approximately 20,000 gpm from open pit drainage and groundwater sources. Presently this inflow is utilized at the mill facility for the concentrating operation, and needs to be maintained to sustain future production. As a result, an underground pumping system is required at GBC Mine to continue this essential supply of water to the mill. This presentation describes the underground dewatering and pumping system that was designed to meet the requirements of the new mine layout. The design entails a dual lift pumping system

comprised of 20 centrifugal slurry pumps in a series pumping application at 600 hp each. Design is near completion and the system is scheduled to be commissioned in December 2016.

**10:25 AM**

15-047

## **Improvements in Underground Mining: Implementation of the Paste Backfill System at the Goldstrike Underground**

*G. Chancellor and J. Gonzalez; Barrick Goldstrike, Elko, NV*

The Goldstrike underground produces ~4,500 ore tons/day utilizing both long hole stoping and underhand drift and fill. The transfer raise that fed the Cemented Rock Fill (CRF) plant was within a planned layback of the Betze-Post pit. This situation left two options: build a new CRF plant or build a pastefill plant including 25,000ft of underground piping. The pastefill option was chosen due to the following: employee health - less trucks reduces the diesel particulate matter underground; environmental - paste uses tailings, reducing the need for long term storage; efficiency- paste placement is faster than CRF, especially for remote areas in the mine; and cost- elimination of haulage and crushing costs plus reduced storage costs for the tailings. Construction of the paste plant began in December 2012 and was commissioned in March 2013. It is the first pastefill plant in Nevada. This paper describes the implementation of the pastefill system. It describes the challenges and solutions resolved in the planning, construction and implementation phases. It details the benefits of the system, design changes, construction schedule, operations and the lessons learned from the project.

**10:45 AM**

## **A New Indonesian Shaft**

*S. Graber<sup>1</sup>, C. Cossio<sup>1</sup>, D. Andriatno<sup>2</sup> and A. Maulana<sup>2</sup>; <sup>1</sup>Mining, Stantec – Mining, Tempe, AZ and <sup>2</sup>Grasberg Underground, PT Freeport Indonesia, Tembagapura, Indonesia*

The Service Shaft (SS) designed for PT Freeport Indonesia's Grasberg Block Cave (GBC) operation is one of the largest underground systems of its kind and the first conveyance system of its type in Indonesia. The system uniquely facilitates the movement of personnel and materials up in elevation from the existing adit access to three operating levels as opposed to a system designed to transport from the surface down to lower elevations. The GBC SS is designed as a vertical, concrete-lined winze, utilizing a double-drum Blair hoisting system. It is 8.5 m in diameter and 355 m in total depth. The shaft will be fitted with a 300 person capacity cage and counterweight service hoisting arrangement, a manway for emergency escape, service pipelines and cabling. The two-deck cage is designed to handle a 38.4-tonne maximum payload for heavy lifting requirements. Details presented include technical design for personnel and material handling, focusing on the safe operation of this conveyance system, and the efforts and challenges of the design and the methodology of bringing the new system into operation. The shaft is currently scheduled to be commissioned in the second quarter of 2015.

Wednesday, February 18

Afternoon

## Coal & Energy: Breathing Air Supplies II

2:00 PM • Wednesday, February 18 • 504

Chair: *R. Fernando, OMSHR, Pittsburgh, PA*

2:00 PM

### Introductions

2:30 PM

### Cryogenic Air Breathing Apparatus (CryoBA) and Liquid Air Fill Station (CryoASFS) for Outby Escape

*D. Doerr<sup>1</sup>, E. Blalock<sup>2</sup>, K. Cohen<sup>3</sup> and D. Bush<sup>4</sup>; <sup>1</sup>Liquid Air Breathing Technology, Inc., Merritt Island, FL; <sup>2</sup>BCS Life Support LLC, Titusville, FL; <sup>3</sup>Innovative Health Associates, Kennedy Space Center, FL and <sup>4</sup>NASA, Kennedy Space Center, FL*

A new technology, cryogenic air, two hour breathing apparatus has been developed and tested. Cryogenic air is stored at a low temperature (-318°F) and pressure (< 135 psi). The apparatus has been subjected to a battery of machine and human tests ( as specified in 42 CFR, part 84). Machine testing on a Posichek<sup>3</sup> demonstrated the ability to maintain a positive mask pressure. Off-vertical performance was also verified. The human testing was accomplished in the NASA Biomedical Lab at the Kennedy Space Center. Representative data to be presented verified that all physiological requirements could be satisfied while providing respiratory protection for a miner. This unit was designed to allow simple, user refilling during a mine egress from the Cryogenic Air Supply and Fill Station (ASFS). Testing of the ASFS verified the ability to perform rapid, simultaneous and/or sequential fills. This testing has confirmed that a cryogenic air supplied, two hour SCBA is feasible while improving safety with extended duration, but eliminate the high pressure hazard of compressed air cylinders.

3:00 PM

### Development of the “SMART SCSR” for Escape

*P. Ream; Research and Development, CSE Corporation, Monroeville, PA*

In order to meet new requirements of the revised CFR 42 Part 84 for Closed Circuit Escape Devices and to introduce new technology to its market and customers CSE Corporation has developed a “Smart” SCSR. This New SCSR (SR2000) is designed to meet and exceed all of the design and performance requirements of this new regulation however it also provides its own on-board set of diagnostics that provides the user with a go...no-go signal as to its readiness for use. The unit will be fitted with a single indicator that will tell the miner and/or his supervisor if the SCSR can be taken to the worksite or needs

to be replaced. This paper will discuss the conditions that are monitored, interpretation of the indicator and the advantages to the miner and to the mining operator in improved compliance, lower overall costs and reduced risk.

**3:30 PM**

## **Mine Tests of a Cryogenic Refuge Alternative Supply System (CryoRASS)**

*D. Doerr<sup>1</sup>, E. Blalock<sup>2</sup> and D. Bush<sup>3</sup>; <sup>1</sup>Liquid Air Breathing Tech., Merritt Island, FL; <sup>2</sup>BCS Life Support LLC, Titusville, FL and <sup>3</sup>Liquid Air Breathing Technology, Inc., Merritt Island, FL*

A new technology Refuge Alternative supply based on a cryogenic gas was developed, tested, and reported to the 2014 SME. This prototype system was modified from its 10 person baseline to a 20 person system and installed in a certified, inflatable Refuge Alternative located in a test mine. Representative heat was added and temperature, pressure, gas concentration, and flow data were digitally monitored. The major benefit of this new technology is the provision of heat stress relief by circulating refuge gases through an air-handler which contains the heat exchangers necessary to warm the very cold (-318°F) liquid air to a gas before adding the required respirable air supply. Further, this process condenses water vapor from the atmosphere thereby lowering humidity. The liquid air supply ran the required 96 hour test and demonstrated a negative delta T across the air handler. Total re-circulated flow through the air distribution manifold was > 100 SCFM. In summary, the liquid air supply provided the necessary oxygen (component in air), while providing heat stress relief via cooling and reduced humidity.

**4:00 PM**

15-043

## **Smart Escape SCBA: Prototype Development of an Oxygen Dosing Filter Self-Rescuer**

*D. Kimball<sup>1</sup>, D. Alexander<sup>3</sup>, R. Fernando<sup>2</sup> and P. Chambers<sup>1</sup>; <sup>1</sup>Avon Protection, Belcamp, MD; <sup>2</sup>OMSHR, NIOSH, Pittsburgh, PA and <sup>3</sup>Technical Products, Inc., Sterling, MA*

The Smart Escape Self Contained Breathing Apparatus was developed under the Office of Mine Safety & Health Research extramural program as one of several new breathing air technology initiatives. The prototype provides open circuit breathing protection and supplemental oxygen to escaping miners. The unit combines with a hooded filter half mask and a CBRN carbon filter with CO catalyst to protect against combustion threat gases. A review of recent US coal mine disasters shows that in each case the ambient air contained over 18% oxygen. Whereas current SCSR's dose 100% oxygen regardless of ambient conditions, the Smart Escape SCBA senses any deficit levels of ambient oxygen and doses only the amount needed to maintain a minimum of 20% oxygen in the mask. The result of this effort is either a unit that provides longer breathing duration or smaller form and lighter weight than current SCSR's. MAN 4 bench tests have demonstrated that oxygen can be supplied as demanded for variable workloads under a wide range of oxygen deficiency conditions. In the Metal/Non-Metal mining industry, this unit could provide an increased level of protection over currently used filter self-rescuers.

## Coal & Energy: Dust Control II

2:00 PM • Wednesday, February 18 • 501

Chairs: **J. Colinet**<sup>1</sup>, NIOSH, Pittsburgh, PA  
**J. Rider**<sup>2</sup>, CDC-NIOSH/Mining Safety and Health,  
Pittsburgh, PA

2:00 PM

### Introductions

2:05 PM

### An Overview of Dust Control Around the Globe

*J. Swanson; Oregon Institute of Technology, Klamath Falls, OR*

The U.S. has pushed forward with its agenda to protect the health of its coal workers by reducing allowable dust concentrations. The rest of the world is watching and some countries are debating similar measures. The benefit of implementing new health and safety measures is difficult to quantify, causing many to hold off on investing in such measures. It is of great interest to evaluate how different countries deal with the health and safety issue of dust control as the health ramifications are not immediately visible as compared to other health and safety issues. In many cases this can be viewed according to the regulations, if and how these are maintained and controlled, what consequences are expected for violations and in some cases an economic evaluation which may include cost of personal injury. A comparison of how different countries are trying to deal with these issues can help to better understand and benefit those trying to improve the health of their own workers.

2:25 PM

### Use of Controlled Flow Transfer Chute Technology to Minimize Airborne Dust

*M. Koca and K. Clancy; Flexco, Downers Grove, IL*

With the industry drive to reduce our workforce exposure to potentially harmful airborne contaminants, mining operators need to look at all sources contributing to airborne dust. Conventional transfer chutes are historically a contributor and fortunately there are methods to dramatically reduce the contribution of airborne dust by incorporating advanced controlled flow transfer chute technology. There are many solutions in the marketplace today that focus on managing the transfer at the receiving belt discharge and using containment and suppression techniques. While these may have their place and serve a function, their ultimate performance is impacted by the total transfer design and how much dust is generated before the receiving belt load point. This presentation will focus on how to keep the dust levels to an absolute minimum from the initial launch from the head pulley to the belt loading on the receiving belt. With reduced particulate introduced into the air, the mine operators can potentially eliminate dust collection and suppression systems, or at minimum, increase the effectiveness of these systems.

**2:45 PM**

15-031

## **Field Evaluation of an Inline Wet Scrubber for Reducing Float Coal Dust on a Continuous Miner Section**

*S. Janisko, J. Colinet, J. Patts, T. Barone and L. Patts; NIOSH, Pittsburgh, PA*

Controlling float coal dust in underground coal mines before dispersal into the general airstream can reduce the risk of mine explosions while potentially achieving a more efficient and effective use of rock dust. A prototype, flooded-bed scrubber was evaluated for float coal dust control in the return of a continuous miner section. The scrubber was installed in line between the ventilation tubing and an exhausting auxiliary fan. Airborne and deposited dust mass measurements were collected over a period of three days at set distances from the fan exhaust to assess the changes in float coal dust levels in the return due to the operation of the scrubber. Mass-based measurements were collected on a per-cut basis and were normalized per foot of advance by the continuous miner. Results show that average float coal dust levels measured under baseline conditions were reduced by over 91% when operating the scrubber.

**3:05 PM**

## **Modern Rock Dust Development and Evaluation**

*R. Eades and K. Perry; Mining Engineering, University of Kentucky, Lexington, KY*

The University of Kentucky conducted inerting tests and angle of ejection tests on five types of rock dust. Two polymerized dusts and a newly developed hydrophobic dust were compared to typical dry and wet dust applications. These three newer products are designed to alleviate respirable dust concerns for dry dusting and caking issues with wet dusting. Samples for both test types were prepared in a laboratory and subjected to temperature and humidity cycles that are typical of an underground coal mine. Inerting tests were conducted in a 38L chamber with a 5kJ Sobbe igniter. Angle of ejection testing was conducted at the University of Kentucky Explosives Research Team Lab in Georgetown, KY. The results from these tests indicate that the newly developed dusts have improved results for flame suppression and ejection when compared to typical wet dust applications. The significance of these results is discussed in regards to existing respirable dust regulations and the issues associated with caking.

## Coal & Energy: Mine Emergency Response

2:00 PM • Wednesday, February 18 • 503

Chair: *M. Trevits, South Park, PA*

2:00 PM

### Introductions

2:05 PM

### Responsible Mine: Mine Disaster Crisis Management and Emergency Response Plans

*J. Gardner; ECSI, LLC, Lexington, KY*

This paper will highlight the issues, concerns and ramifications noted in a chapter of a new SME publication entitled Responsible Mining: Sustainable Practices in the Mining Industry. The Presentation gives a sneak preview of the chapter on crisis management which analyzes a systematic crisis management response to a mine disaster from the operational and legal perspectives. In addition, the Presentation will delve into the MSHA regulatory requirements for an Emergency Response Plan. While each situation is different, there are general guidelines for forming an effective plan of action. The first concern, of course, in any disaster is the protection of human life. The next concern is whether any assistance is needed on any front because of the magnitude of the situation. A constant consideration is "damage control." That is, keeping the field situation and potential liability from getting worse, more complicated or both.

2:25 PM

15-055

### Mine Escape Vehicle Technology Evaluation

*S. Cotten<sup>2</sup> and L. Giraldo<sup>1</sup>; <sup>1</sup>Special Missions, Raytheon UTD, Springfield, VA and <sup>2</sup>Underground Novelties, Lockport, NY*

A Mine Escape Vehicle (MEV) may allow personnel to evacuate a mine as the first and most desirable response to any underground emergency. Under a NIOSH contract, Raytheon developed a design for a vehicle that coal miners could use to facilitate rapid exit from a mine in the case of fire or explosion. Vehicle requirements included enhanced life support and operation in a low or no visibility atmosphere. The resulting MEV concept was centered upon retrofitting existing mine personnel carriers with available, mine-worthy equipment. Subsequently, a proof-of-concept MEV was constructed, tested, and placed into routine operation in an underground coal mine for 7 months. Sensor limitations observed during the in-mine evaluation and technology development that occurred after vehicle sensor selection prompted NIOSH to fund an investigation of improved technologies that might offer the MEV occupants improved situational awareness. This paper summarizes evaluations of new atmospheric gas monitors and radar and lidar sensors for vehicle guidance.

**2:45 PM**

15-074

## **Comparison of Coal Mine Emergency Management and Rescue Practices in Germany and the United States**

*J. Brune<sup>1</sup>, M. Anderson<sup>1</sup>, J. Kretschmann<sup>2</sup> and W. Hermülheim<sup>3</sup>;  
<sup>1</sup>Mining Engineering, Colorado School of Mines, Golden, CO;  
<sup>2</sup>Mining Engineering, TFH Georg Agricola University, Bochum, Germany and <sup>3</sup>Mining Engineering, Technical University Clausthal, Clausthal, Germany*

This paper analyzes mine emergency management and rescue practices in German underground coal mines and compares them to those used in the United States. The German mining industry has developed these practices over more than 100 years, and they have successfully managed numerous fire, water inundation and ground control emergencies. The authors interviewed German mine emergency professionals about rescue team and emergency operations and will identify procedures and best practices that may be of interest to the United States mining industry.

**3:05 PM**

## **International Mine Rescue Comparison: Australia, Canada, Germany, and the United States of America**

*N. Henderson<sup>1</sup> and J. Brune<sup>2</sup>; <sup>1</sup>Health and Safety, Freeport McMoRan, Empire, CO and <sup>2</sup>Mining Engineering, Colorado School of Mines, Golden, CO*

Mine rescue is an important part of the mining industry and varies internationally. This paper will analyze the mine rescue structures in Australia, Canada, Germany, and the United States of America. The report will look at each country individually and cover the legal requirements, the membership qualifications, program structure, training systems and requirements, and strengths of each program. With mining being such a global industry, it is important to learn from the improvements other countries have made as well as to critically analyze the current systems for weaknesses.

## **Coal & Energy: Ventilation Innovations II**

**2:00 PM • Wednesday, February 18 • 502**

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

**2:00 PM**

## **Introductions**

2:05 PM

15-059

## Barriers and Incentives: The Application of Comprehensive Risk Management in the US Underground Coal Mining Industry

*J. Restrepo<sup>1</sup>, K. Luxbacher<sup>1</sup>, B. Hebblewhite<sup>3</sup>, P. Kirsch<sup>2</sup> and R. Mitra<sup>3</sup>; <sup>1</sup>Mining and Minerals Engineering, Virginia Tech, Christiansburg, VA; <sup>2</sup>University of Queensland, Brisbane, QLD, Australia and <sup>3</sup>University of New South Wales, Sydney, NSW, Australia*

The reoccurrence of multiple fatality events in the US underground coal mining industry, specifies the need for improved methods of major safety hazard identification and control. While many solutions to reducing the risk of mine disasters have been proposed including stricter regulation and improved technology, a comprehensive risk management approach has yet to be fully integrated in the US mining industry. This research reviews the development of mine safety regulation in the US, and identifies regulatory constraints which have affected the diffusion of risk management. Comprehensive risk management systems have been developed and implemented across a multitude of heavy industries, most notably the Australian minerals industry. This paper examines the successful application of risk management in these industries, along with barriers towards US implementation of risk management, which include the existence of competing safety models (e.g. behavior-based safety) and compliance regulation which consumes company resources. Steps towards the risk-based approach, including increased regulatory pressure and proactive initiation by high-ranking industry individuals are also proposed.

2:25 PM

15-026

## Turbulent Models for Pollutant Transport in Open Pit Mines under Stable Boundary Layer

*K. Raj<sup>1</sup>, S. Bandopadhyay<sup>1</sup> and R. Ramani<sup>2</sup>; <sup>1</sup>Mining and Geological Engineering, University of Alaska Fairbanks, Fairbanks, AK and <sup>2</sup>Mining and Geo-Environmental Engineering, The Pennsylvania State University, University Park, PA*

Air flow situation in an open pit mine is not known a-priori; therefore, use of models is common. Consequently, it is necessary to investigate various models as to their ability to simulate the flow phenomena and to predict the contaminant distributions within the pit with reasonable accuracy. Pollutant transport models, however, differ in their complexity, accuracy, assumptions, structure, and algorithm; as a result, predictions vary from model to model. In this paper, the results of a computational fluid dynamics (CFD) modeling study of pollutant transport in an open pit mine under stable boundary layer are presented. Measured data are used to compare results of two CFD models: Large Eddy Simulation model and kappa-epsilon ( $\kappa$ - $\epsilon$ ) model. Despite the complex synoptic situations and different meteorological input data, the simulation results from both the models are in good agreement regarding the dispersion of pollutants.

2:45 PM

15-086

## **Impact of Regulator Settings on the Formation of Explosive Gas Zones in Bleeder Ventilated Longwall Gobs**

*R. Gilmore<sup>1</sup>, J. Marts<sup>2</sup>, J. Brune<sup>2</sup>, S. Saki<sup>2</sup>, G. Bogin<sup>1</sup> and J. Grubb<sup>2</sup>; <sup>1</sup>Mechanical, Colorado School of Mines, Golden, CO and <sup>2</sup>Mining, Colorado School of Mines, Golden, CO*

Researchers at the Colorado School of Mines have studied the influence of headgate side ventilation controls near the longwall start-up room on the formation of explosive gas zones (EGZs) in underground coal longwall bleeder ventilated gobs. In a project funded by the National Institute for Occupational Safety and Health (NIOSH) researchers developed a Computational Fluid Dynamics (CFD) model to study the formation of methane-air mixtures in the gob, start-up room, and bleeder entries. The relative change in size and location of EGZs are examined in response to ventilation controls in the headgate side bleeder entries near the start-up room. Modeling suggests that adjustments to the ventilation controls can be made to minimize the size of the EGZ. However the EGZ may form in or around active working areas regardless of the ventilation control settings. Research found regulators on the crosscuts into start-up room and first entry inby can force air into to crosscuts outby the start-up room causing more air to flow through the gob.

3:05 PM

15-017

## **Important Constraints and Their Consequences in 3-Dimensional CFD Modeling of Open-Pit Mines using CRADLE**

*T. Bhowmick, K. Raj and S. Bandopadhyay; Department of Mining and Geological Engineering, University of Alaska Fairbanks, Fairbanks, AK*

Computational fluid dynamics (CFD) modeling of an open-pit mine has several challenges. Good quality tetrahedral meshing and insertion of prism layers in faceted open-pit mine geometry is complicated due to presence of numerous vertices and ridges. Vertices and ridges result in poor quality tetra elements and hole in prism layers, which cause instability in the model. The presence of good quality pit bottom prism layers significantly improves the formation of velocity boundary layer and thermal boundary layer at the pit floor. This results in an expected temperature dependent micrometeorological buoyancy flow in the pit. Whereas, geometry without a prism layer results in an abrupt temperature gradient near the pit floor. Buoyancy flow and recirculation have significant effect in lifting mechanism of fugitive dust particles generated near pit floor. Good quality meshing, appropriate choices of initial and boundary conditions and selection of turbulence model have significant influences on the simulation results. This paper presents some important constraints and their consequences in CFD modeling of different geometries of an open-pit mine using CRADLE CFD.

**3:25 PM**

15-029

## **CFD Analysis on Gas Distribution for Different Scrubber Redirection Configurations in Sump Cut**

*Y. Zheng<sup>1</sup>, J. Organiscak<sup>1</sup>, L. Zhou<sup>2</sup>, T. Beck<sup>1</sup> and J. Rider<sup>1</sup>;*

*<sup>1</sup>Dust, Ventilation and Toxic Substances Branch, National Institute for Occupational Safety and Health, Pittsburgh, PA and*

*<sup>2</sup>Fires and Explosions Branch, NIOSH, Pittsburgh, PA*

The National Institute for Occupational Safety and Health (NIOSH), Office of Mine Safety and Health Research (OMSHR) has recently developed a series of models utilizing Computational Fluid Dynamics (CFD) to study gas distribution around a continuous mining machine with various fan-powered flooded bed scrubber discharge configurations. CFD models were constructed to evaluate the redirection of scrubber discharge toward the mining face rather than behind the return curtain. Three redirection cases were built and compared to a model with a conventional scrubber discharge where air is directed away from the face into the return. The CFD models were calibrated and validated based on experimental data and accurately predicted gas levels at four gas monitoring locations. One additional prediction model was simulated to consider a different scrubber discharge angle. These models identified relatively high gassy areas around the continuous miner which may warrant their use in coal mines with medium to high methane liberation rates. This paper describes the methodology used to develop the CFD models, and the validation of the models based on experimental data.

## **Mineral & Metallurgical Processing: Remediation and Secondary Processing: Tailings**

**2:00 PM • Wednesday, February 18 • 710**

*Chairs: B. Erfourth, Barr Engineering, Minneapolis, MN*

*L. Schlink, Freeport-McMoRan Copper & Gold, Oro Valley, AZ*

**2:00 PM**

## **Introductions**

**2:05 PM**

15-022

## **Selection Criteria for Mixing Systems for Tailings, Paste-back Filling & Conditioning**

*B. Perlmutter and S. Bentley; BHS-Sonthofen Inc., Charlotte, NC*

There are many challenges for tailings conditioning and disposal and for producing paste-back filling. These include the quality of the paste, recipe optimization, blending of binders, production, etc. One area of great impact is the mixing of the components to form the paste. The paste is a network of fine particles,

mixed together, to achieve the required strength and viscosity. This paper discusses the methods of mixing as alternatives to conventional concrete mixing. When selecting a mixing technology, several parameters are examined. These include the type of process (continuous, batch, overflow or bottom discharge), grain sizes, moisture content, grain characteristics (abrasive or sticky), binders and the required retention or mixing time to achieve a high-level of homogeneity of the mix design. The paper begins with the principles of mixing and the lab tests for determining the mixer type and operating parameters. Case history details follow for tailings, paste-backfilling and binder/fly ash mixing. The benefits of efficient mixing are discussed which can lead to cement reduction. Finally, information is presented for deciding on a mixing technology.

**2:25 PM**

## **High Speed Dewatering of Tailings**

*D. Harris; Genesis Water, Centennial, CO*

Dewatering tailings in a settling pond is facing increasing regulatory roadblocks. New mines have difficulties obtaining permits to build a facility. Established mines are running out of space to add additional material to their existing ponds. An approach using flocculation and a rapid dewatering screening system is currently being tested on a small scale with mine tailings. The goal is to achieve continuous, rapid water release from the slurry and increase solids concentration to a desired level. For some operations this target is a material that can be pumped to the disposal site. In other mine sites, the ideal filter cake has sufficient strength to be dry stacked. The dewatering process involves removal of the free-water phase from the slurry, using the screening system aided by polymer. A small scale demonstration took place to evaluate the flocculation dosing scheme and rapid dewatering equipment for primary and secondary dewatering re-lease. The process economics proved to be significantly cheaper than other treatment methods such as presses or centrifuges.

**2:45 PM**

15-097

## **Iron Control in Target Streams**

*P. James and M. Baker; Blue Planet Strategies, Madison, WI*

Dissolved iron present in mining liquid process streams such as PLS (pregnant leach solution), raffinate, or bleed streams in either or both ferric (Fe+3) or ferrous (Fe+2) states can be beneficial or detrimental to the target process depending on the process specifics. Here potential application of DEMET technology for controllable, cost-effective, on-the-fly control and adjustment of target iron levels described. This new and recently demonstrated application for BPS's versatile DEMET dilute source metal recovery and concentrating technology allows DEMET to provide avenue for control of the target stream chemistry to improve production. A discussion of the process and examples of relevant chemistry is will be presented. Representative results from treatment of a target mine waste stream will also be examined. Efficient ferric elimination and conversion to ferrous at practical rates will be shown. Ferrous reduction to iron metal and ferrous oxidation to ferric will also be discussed.

Combinations of various target reactions to achieve the desired iron species control are considered and process economics will be highlighted.

**3:05 PM**

## **Influential Factors in Determination of Sustainability in a Tailings Storage Facility**

*D. Gilbert; Minera Taboca, Manaus, Brazil*

Too often, Tailings Storage Facilities (TSF) do not receive the proper support in during the planning, and operations stages of a mine. This fact is demonstrated in a number of recent environmental incidents at TSF throughout the world. Environmental consequences are not the only measures by which a mine can evaluate the quantifiable risk and opportunity present in a TSF operation. Other metrics include pump operating costs, dam construction, contractors, etc. These can be assembled and considered as moving targets made more agreeable by lowering the negative consequences. Negative consequences may include fines, environmental incidents, high costs, unplanned shutdowns, exceedances, etc. Similarly, closure plans too often are generic, and not considered during mine operation. Real time value of closure cost can be lowered by using innovation and best practices, as the primary drivers for an efficient TSF operation.

**3:25 PM**

## **Sustainable Coal Waste Disposal**

*M. Rezaee and R. Honaker; Mining Engineering, University of Kentucky, Lexington, KY*

This paper addresses sustainable coal waste disposal strategies to minimize the environmental impacts, meet the society demand and evaluate the potential extraction of critical elements such as precious metals and rare earth elements as the by-product of the coal related waste material. To assess strategies aimed at minimizing the impact of disposal of coal waste materials on the environment, two long-term leaching experiments of up to five months duration were performed using sized-density fractionated waste materials from three plants cleaning high, medium and low sulfur bituminous coal. The tests evaluated the mobility of major trace elements under different disposal scenarios: (i) a static leaching test designed to simulate the quiescent conditions in a stable impoundment, and (ii) a dynamic test to simulate waste materials exposed to the atmosphere, either in variable wet/dry storage conditions, or in unusual circumstances like those resulting from breaching of an impoundment containment wall. The fractionation of the major and trace elements, precious metals and REE in processing plants were also evaluated. The results are discussed in this paper.

**3:45 PM**

15-020

## **Novel Method to Locate and Profile the Bed in a Thickener**

*J. Johnson<sup>1</sup>, R. Cook<sup>1</sup>, B. Housley<sup>1</sup>, L. Linton<sup>2</sup>, D. Scott<sup>3</sup>, J. Easton<sup>3</sup> and J. Stanley<sup>3</sup>; <sup>1</sup>Paste Thickening, WesTech Engineering, Salt Lake City, UT; <sup>2</sup>Membrane Filtration, WesTech Eng., Salt Lake City, UT and <sup>3</sup>Engineering, WesTech, Salt Lake City, UT*

Measuring the mud bed level in a sedimentation device is an important control variable. Methods used to date for this purpose have had limited success providing continuous, consistent measurements at a reasonable price. This paper describes a new instrument for detecting the mud bed / liquor interface as well as bed density profiles. The state of the bed is measured directly with sensors located in the thickener. Data from bench-scale and full-scale tests show that the bed level is well defined and easily detected. In addition, full-scale testing revealed unprecedented information about thickener beds. Variations in bed density gave new insight into thickener bed dynamics, providing design and control opportunities never before possible. This novel instrument can significantly improve thickener control by providing reliable and consistent bed level measurements. It is also capable of measuring bed density profiles that can potentially identify significant operating problems early enough to take corrective action before experiencing costly shut downs.

## **Mineral & Metallurgical Processing: Separation: Physical Separation**

**2:00 PM • Wednesday, February 18 • 708**

*Chairs: S. Miskovic, University of Utah, Salt Lake City, UT  
D. Perkins, Derrick Engineering, Buffalo, NY*

**2:00 PM**

### **Introductions**

**2:18 PM**

### **Upgrading Potential Using Ore Sorting Technologies**

*R. Honaker<sup>1</sup>, M. Mahmoodabadi<sup>1</sup> and G. Luttrell<sup>2</sup>; <sup>1</sup>Mining Engineering, University of Kentucky, Lexington, KY and <sup>2</sup>Mining & Minerals Engineering, Virginia Tech, Blacksburg, VA*

Developments in ore sorting technologies have provided the ability to achieve economic dry pre-concentration of ores prior to a grinding/concentration circuit and, in some cases, produce a high grade concentrate of sufficient quality for end use. The use of dual X-ray transmission (XRT) sorting has been proven to provide efficient separations for materials such as coal at throughput capacities greater than 100 tph. A recently completed study evaluated the use of XRT sorting on anthracite coal with difficult cleaning characteristics at a mass flow rate of 120

tph. Excellent separation efficiencies were obtained on 60 x 10 mm material as indicated by probable error values less than 0.10. This publication will review the current status of ore sorting technologies and their applications along with a detailed presentation of the separation results obtained using XRT-based sorting.

**2:36 PM**

## **Phosphorus Removal from Manganese Carbonate Ore by Magnetic Separation and Flotation**

*Z. liu; Chemical Engineering, Chongqing University, Chongqing City, China*

Manganese metal or ferromanganese is important for steelmaking, the contents of impurities, especially that of phosphate and sulfate, are important factors for final product quality. Studies indicated that more than 80% of phosphorus in the manganese products is introduced from manganese ore. Development of new dephosphorization technology for high phosphorus manganese ore such as manganese resource in Cheng Kou, China is needed. For this purpose, the removal of phosphorus compounds from manganese ore by magnetic separation and reverse flotation was studied. The results indicated that the phosphorus content was decreased to 0.66% from 2.23% with Mn grade of 31.3% and 80.78% recovery after high intensity magnetic separation. After further flotation the phosphorus was decreased to 0.35% with Mn grade of 33.4% and 85% flotation recovery.

**2:54 PM**

## **Comparison of Dispersants for Selective Flocculation of Hematite Ore**

*H. Haselhuhn and S. Kawatra; Chemical Engineering, Michigan Technological University, Houghton, MI*

Selective flocculation and dispersion is a process used to separate finely liberated (<25 $\mu$ m) hematite ore from gangue minerals. It requires a specific water chemistry, a selective flocculant and a dispersant to yield an effective separation. This research focused on finding the most effective dispersant for the hematite concentration process using a laboratory scale continuous deslime thickener. The dispersants studied were sodium silicate, sodium hencosapolyphosphate (21-member polyphosphate), 2000 molecular weight (MW) polyacrylic acid (PAA), 4000 MW PAA and 7000 MW PAA. It was found that sodium hencosapolyphosphate at 0.05 pounds of dispersant per ton of ore yielded the best grade/recovery curve for iron. The 4000 MW polyacrylic acid at 0.25 pounds of PAA per ton of ore had an iron grade/recovery curve nearly that of sodium hencosapolyphosphate but yielded a lower phosphorus concentration in the product (down to 0.022% P).

**3:12 PM**

## **Ablation – Breakthrough Technology to Reduce Uranium Mining Costs and Increase Resources**

*D. Scriven; Ablation Technologies, Casper, WY*

Ablation Technologies, LLC has developed and patented a revolutionary mining technology termed “ablation”. Ablation is a process using only mechanical forces to upgrade sandstone uranium ores. Uranium bearing sandstone ore bodies are formed when uranium enriched solution flowing through an aquifer and fines some type of a “red/ox” zone forcing the uranium and other heavy metals to come out of solution. The precipitate forms a thin coating on the sand grains and fills the interstitial space between the sand grains but does not penetrate the sand grains. The ablation process knocks the precipitate off the sand grains using the forces of abrasion, elastic compression and rebounding, much like a mud coated tennis ball will shed the mud when bounced off the ground, and to some extent, sonic waves. This produces a product which collectively is exactly the same as the ore going in but with all the individual components separated. This allows for discretionary separation, the most important of which is screening.

**3:30 PM**

## **Screening and De-Sliming Coal on a Derrick Single Deck Stack Sizer**

*R. Reeves; Hazen Research, Golden, CO*

Metallurgical coal producers are challenged to maintain market share because of falling prices and rising production costs. Metallurgical coal must possess critical physical and chemical properties that are not readily apparent with laboratory analyses. To solve this problem, several producers have provided 1 to 2 ton bulk samples for test at their client’s facilities. Hazen Research, Inc., has been retained to operate a pilot-scale coal washing facility specifically designed, using heavy media, spiral and flotation circuits, to produce these bulk samples. Flotation feed and spiral feed was initially produced by screening raw coal on circular vibrating screen in two separate operations at 100 mesh (150  $\mu\text{m}$ ) and at 325 mesh (50  $\mu\text{m}$ ). Capacity was less than 100 kg/h and required two full time technicians. These conditions were unacceptable, so Hazen replaced the circular screen with a high capacity Derrick Single Deck Stack Sizer. The Stack Sizer was customized to deslime and screen feed on a single deck.

**3:48 PM**

## **Increasing Productivity and Profitability in Mineral Processing Plants**

*G. Barrios<sup>2</sup>, J. Vizcarra<sup>1</sup> and B. Aquino<sup>1</sup>; <sup>1</sup>El Brocal, Lima, Peru and <sup>2</sup>Goldex S.A., Lima, Peru*

In the last years the mining industry due to the effect of continuous decrease of metal prices and increase of operation costs that has impacted the economic performance of Mineral Processing Plants. These effects made extremely necessary to optimize productivity and profitability in actual mineral process-

ing plants by utilizing new technologies to improve plant operations. Sociedad Minera El Brocal located in Cerro de Pasco-Peru, have went under concentrator expansions by using new equipment to optimizing classification in the grinding circuit, by installing a washing plant to separate sticky clay, by installing a fines lead/zinc flotation circuit, and by using other techniques that successfully improved operation performance that achieved a positive economic situation. This paper describes our actual successful working operation that increased productivity and profitability to the company. It was important to make these technology changes in our mineral processing plant to balance the negative situation of the effects mentioned that can become worse in the next years.

**4:06 PM**

15-025

## **Newmont USA and Derrick Corporation Collaborate on Technological Advancements of Screen Surface Technology on Gold Processing Plants**

*E. Mortensen<sup>1</sup> and M. Zaska<sup>2</sup>; <sup>1</sup>Process Machinery Associates, Reno, NV and <sup>2</sup>Newmont USA, Golconda, NV*

As mine operators continuously look for ways to improve functionality and increase capacity of their facilities, existing process equipment is often pushed to and past its designed limitations. As a result, equipment manufacturers are asked for economical solutions to meet redefined processing needs. Newmont USA (Newmont) in Nevada was faced with such a need in their Carbon-in-Leach (CIL) train. In a collaborative effort between Newmont and Derrick Corporation, tests were conceived to assess the viability of drop in replacement screen using a three dimensional screen panel. The urethane pyramid screen panel was designed to increase flux while maintaining the existing equipment footprint. The test is the end result of an ongoing research and development project that Derrick undertook in an effort to refine and upgrade their urethane screening media. The application of this new screening media is presented for this CIL application along with future plans to implement the technology in trash, safety, carbon dewatering, carbon sizing, and other scalping applications.

## **Mining & Exploration: Geology: Geological Engineering/Geotechnical**

**2:00 PM • Wednesday, February 18 • 703**

*Chair: E. Kim, University of Utah, Salt Lake City, UT*

**2:00 PM**

## **Introductions**

2:05 PM

## **Subsidence Potential Analyses of an Illinois Coal Mine**

*S. Zamiran<sup>2</sup> and A. Osouli<sup>1</sup>; <sup>1</sup>Civil Engineering, Southern Illinois University Edwardsville, Edwardsville, IL and <sup>2</sup>Civil Engineering, Southern Illinois University, Carbondale, IL*

The subsidence risk and potential damage evaluation is part of evaluation analyses of abandoned mines. The subsidence can be the result of roof, pillar, or floor failures. It is not uncommon that mines become flooded sometime after abandonment. In some cases, mine companies inject the slurry of coal refuse to abandoned areas as a disposal method. Despite the advantages of using slurry backfilling process for abandoned mines, this process may result in deterioration of mine stability. This instability specially should be taken into considerations in coal mines with underclay floor which its strength property would be reduced after slurry injection. In this study, the stability of floor and pillar in a coal mine in Illinois is investigated in two phases. The first phase includes stability investigation of floor and pillar during the operation of the mined out zones. The second phase contains the analyses after the slurry backfilling of the mine. Consequently, the likelihood of the subsidence due to pillar or floor failure is evaluated. The subsidence profile of the panel is constructed and the effect of moisture exposure to floor and pillar are discussed.

2:25 PM

## **Collaborative Approaches to Solving Geotechnical Challenges in the Mining Environment**

*C. Lange; Nicholson Construction Company, Centennial, CO*

Geotechnical construction in the mining environment includes earth retention systems and deep foundation systems. The geotechnical contractor is versed in a variety of techniques and construction means and methods that allow the geotechnical contractor to optimize solutions given the particulars of the site access constrains, ground conditions, performance criteria and geotechnical risk. Mining owner collaboration between the design team and geotechnical contractor allows selection of the optimum solution. Two case studies are discussed that showcase this collaboration; a contractor-designed earth retention system and a contractor-design deep foundation system each of which offered a price and schedule savings over the original solutions.

2:45 PM

## **A New Era of Geotechnical and Hydrology Monitoring at Rio Tinto Kennecott Utah Copper**

*B. Ross; Rio Tinto Kennecott Utah Copper, Salt Lake City, UT*

The Geotechnical Department at Rio Tinto Kennecott Utah Copper predicted the 2013 Manefay Slide more than a month before the slide occurred with state of the art monitoring. This early warning was instrumental in preventing fatalities and injuries as a result of the world's largest mining landslide. Since

the Manefay Slide the Geotechnical Department has gone through a number of modifications that has included additional people, monitoring equipment, analysis methods and structural changes. The intention of these changes is to not only improve on an excellent monitoring program to keep people safe, but to increase the resources and capabilities to prevent future slides from happening. This paper discusses the changes that have been made in Kennecott's Geotechnical Department and how those changes are making a difference for the future of the mine.

**3:05 PM**

## **Characterizing Pre-Cursor Parameters of Frictional Ignitions**

*E. Kim; University of Utah, Salt Lake City, UT*

The 2010 explosion at the Upper Big Branch Mine in West Virginia is believed to have been started by frictional ignition, the impact between a coal cutting bit and rock. Frictional sparking occurs when rock is cut, which can potentially ignite methane gas leading to explosions. Thus, it is important to understand frictional ignition mechanisms that may occur during the excavation process. The objective of this study was to delineate possible remedies for preventing or minimizing frictional ignitions thereby contributing to improved safety in the mining industry. The main parameter investigated was skew angle, which was tested at 0, 3, 6, 9, 12, and 15° with four cutting tools. Tests conducted for the longer time period (200 sec) exhibited greater effects on temperature increase at the bit tip for all skew angles. Skew angles higher than 6° in long time duration tests significantly increased temperatures of both bit tips and rock wheels except for one of the bit tips.

**3:25 PM**

## **An Experimental Study of Rock Stress Redistribution for Caprock Integrity in Geological CO<sub>2</sub> Sequestration by Using Seismic Tomography Techniques**

*E. Sun, D. Westman, B. Fahrman and X. Ma; Mining and Minerals Department, Virginia Polytechnic Institute and State University, Blacksburg, VA*

This experimental study applies a uniaxial compressive load on a granite sample to analyze the stress redistribution for the long-term in-situ caprock integrity in the CO<sub>2</sub> injection. The induced seismic waves are recorded by passive seismic sensors while the locations of the seismic events are calculated based on the Geiger algorithm. Furthermore, the seismic data is divided into four regimes based on the frequency of seismic events correlated with the failure evolution. The travel times and distance charts are plotted to examine the velocity changes in each of the regimes. Finally, the double difference tomography algorithm is applied to recalculate the locations of seismic events and velocity structure in each regime. The results indicate that the passive seismic system has the potential to map the Caprock stress distribution and allow for imaging of the Caprock integrity. Double-difference tomography is a useful method for characterizing the local velocity structure and for evaluating the caprock failure in the CCS project on field.

**3:45 PM**

## **Direct Shear Testing of Rock Specimens from Nevada Gold Mines**

*P. Tiwari, R. Thareja and R. Kallu; Mining and Metallurgical Engineering, University of Nevada Reno, Reno, NV*

Various factors affect shear behavior of insitu rock joints including joint orientation, water seepage, friction angle, cohesion of particles and many more. Proper consideration of these parameters is necessary during experimental investigation in order to correctly evaluate the shear behavior. These concerns require proper understanding of the basic mechanics of discontinuity and the principals involved in their shear deformation. This can be achieved through laboratory testing on natural rock core samples or laboratory testing on physical model. In the present paper the detail account of test results of direct shear tests performed on rock joints is presented. Rock samples are obtained by core drilling in an underground gold mine in Nevada. These rock samples containing joint are used to perform direct shear strength test. Results obtained from tests such as friction, cohesion, normal and shear stiffness of particles are used to develop numerical model for further more investigations. Numerical model calibration is done to the laboratory test data. A numerical parametric study is done to analyze the behavior of rock at different stress conditions.

## **Mining & Exploration: Management: General Management**

**2:00 PM • Wednesday, February 18 • 706**

*Chairs: L. Freeman<sup>1</sup>, CH2M HILL, Denver, CO*

*S. Rosenthal<sup>2</sup>, Newmont Mining Corporation, Greenwood Village, CO*

**2:00 PM**

## **Introductions**

**2:05 PM**

15-091

## **What a Ride: Mining Industry to University**

*S. Rosenthal; Mining Engineering, Montana Tech, Butte, MT*

This paper will share my 'shift in career direction' journey from corporate mine engineer, with 31 years of mining various commodities with a wide range of responsibilities in a variety of countries, to the world of academia. There are times in one's career that a change is required, albeit perhaps not as drastic of a change as moving to teaching. This paper will share how the transition arose, the decision to make the change, the challenges of the first year in academia, and the journey within academia going into the second year.

**2:25 PM**

## **Assertive Leadership Needed as Domestic Minerals and Metals Production is Being Stymied by Opponents**

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

Well-funded environmental groups are trying to prevent mines from securing even insignificant exploration permits. Their plan is to kill mining projects before they get started. They use sophisticated grassroots and social media programs to make obtaining permit approvals exponentially more difficult, expensive, and time consuming, raising the risk of a project denial. Opponents are controlling the agenda of debate, making it appear like no one is in support of mining, and pressuring regulators to deny mining permits. This situation is especially acute on Federal land in the U.S. And Canada is not far behind with its growing social activism against mining. The mining industry and company executives need to take a proactive approach to win public support in order to secure necessary permits. John Davies will make recommendations on how to build and mobilize public support to succeed in highly contentious environments. Attendees will learn how to: create compelling messaging through research, effective communication techniques, build trust and acceptance, identify, motivate, educate, and mobilize supporters, and use modern psychology and social media to shape public opinion

**2:45 PM**

**15-094**

## **Recruiting Future Mining Engineers**

*P. Conrad and S. Rosenthal; Mining Engineering, Montana Tech, Butte, MT*

Despite the recent downturn in the mining industry, Mining Engineers remain in demand. Job opportunities in the United States still exceed the number of students graduating from college with degrees in Mining Engineering. Although enrollment is up for freshman studying Mining Engineering, many of those students will either change majors or not complete their degree, maintaining that deficit of available Mining Engineers. What can be done to ensure that enough Mining Engineers will graduate to fill the needs of the mining industry over the next ten to 20 years? The authors believe that this need can be met by recruiting students to Mining Engineering programs who are genuinely interested in working in the mining industry. With this in mind, Montana Tech conducted its first Mining Engineering camp in July 2014 to get junior and senior high school students interested in careers in the mining industry by showing them that Mining Engineering is both an exciting and rewarding career. This paper discusses What a Blast! The 2014 Montana Tech Mining Camp.

3:05 PM

15-009

## **Explorations in Pursuit of Risk-Based Health and Safety Management Systems**

*P. Yorio and D. Willmer; Office of Mine Safety and Health Research-Human Factors Branch, National Institute for Occupational Safety and Health, Pittsburgh, PA*

The current paper presents the results of a study designed to explore the types of practices which are fundamentally important to developing and maintaining a comprehensive risk-based, health and safety management systems (HSMS) in mining organizations. 18 practicing H&S executives, managers, and professionals from a variety of mining commodities were asked to assess the fundamental importance of 20 distinct elements and 133 different practices assembled from a review of several HSMS consensus standards. The research approach assumes that developing and or maintaining a robust HSMS requires unwavering attention to activities designed to either: 1) directly contribute to a risk management system's plan-do-check-act cycle; and/or 2) build an organization's internal infrastructure without which the cycle cannot be sustained. The results of this study suggest that the following areas require consistent focus and attention: Leadership Development; Accountability; Knowledge, Skills, Ability Development; System Coordination; Culture Enhancement; Behavior Optimization; and Risk Management Studies. Each element and their corresponding top ranked and rated practices are discussed.

3:25 PM

## **Management Systems Alignment: The Missing Step in Performance Optimization**

*K. Sever; OptimiZ Consulting LLC, Gilbert, AZ*

Optimization is a different goal than improvement. Reaching for tomorrow's potential requires a different management strategy. Mines often focus on equipment to achieve optimization, unaware that millions in additional profit depend on people that understand potential and can do what they need to do safely to capture it. Optimization starts in the mind and requires a shift in thinking from "Can we meet budget?" to "How good can we be?" This shift MUST OCCUR to achieve and sustain optimization and it STARTS with the management team. And here is management's dilemma... Traditional management systems reflect actuals, budget/forecast and the organization structure. They were NOT DESIGNED to help identify or capture potential OR create the culture needed for an optimization focus. This "misalignment" creates hidden barriers that cause significant losses, hide potential, divide people and prevent an optimization culture from forming. Findings from a 3-year study of barriers to optimization will be shared, including the impact of misalignment on profit, culture and change. Barrier examples and mining case studies will raise awareness about this missing step in optimization.

**3:45 PM**

## **Using Data Driven Performance Management Systems to Better Manage a Unionized Work Force**

*S. Gant and S. Dessureault; MISOM Technologies, Tucson, AZ*

Colloquial evidence suggests that managing a unionized workforce can create challenges relating to workforce flexibility, communication, and labor contracts, rendering traditional management methods ineffective. Some of the more costly situations, in terms of time and management attention, arise from a handful of employees who are protected by negotiated labor contracts that are governed by complex rules and laws. These employees can cost mines millions of dollars annually while removing under performing employees can also be costly without clear management systems. A complete performance management system can be established allowing for the proper management of these unfortunate situations. The foundation of the system is the automated collection and processing of data from multiple sources into a single analytical platform. A set of tools can be developed to identify and manage inefficient processes and behaviors that reduce productivity. These tools are particularly effective in a union environment. A case study is used to communicate the benefits of a data-driven performance management system including personal anecdotal experience from a former mine-manager at a unionized coal mine.

## **Mining & Exploration: Operations: Mine Planning and Geotechnical Interactions**

**2:00 PM • Wednesday, February 18 • 702**

*Chair: C. Weber, Newmont Mining Corp, Greenwood Village, CO*

**2:00 PM**

## **Introductions**

**2:05 PM**

## **From Optimized Pit Shell to Final Design – Tricks and Traps**

*J. Johnson; Open Pit Technical Services, Barrick Goldstrike, Elko, NV*

With today's available software and computing power, optimized pit shells can be rapidly generated. However, turning Lersch-Grossman shells into a mineable design which honors the optimization parameters is both time consuming and tricky if the user does not keep in mind the underlying assumptions of the optimization run. This presentation provides examples of useful tricks and some common traps encountered when building a pit design from an optimized shell.

2:25 PM

## **Monitoring and Performance of a Mine Waste Dump Constructed on Weak Foundation Materials for Optimized Mine Planning**

*W. Newcomen, E. Coffin and B. Pierce; Geotechnical, BGC Engineering, Kamloops, BC, Canada*

Gibraltar Mines Ltd. plans to construct portions of their 7 Waste Dump on silty waste materials extracted from the Granite open pit area during pre-stripping operations carried out in the 1970's in the early stages of the mine life. The 6 Wrap Dump, a wrap-around waste rock lift, was successfully constructed in 2013 on top of waste materials with similar geotechnical characteristics. An important factor the stability of the 6 Wrap Dump was the pore pressure in the silty waste materials and the underlying glacial tills. As part of the stability performance evaluations, eight vibrating wire piezometers were installed to monitor the pore pressure response in the foundation of the dump during waste rock loading and dump advance. The waste dump advance rates were incrementally increased in an attempt to push the dump as close to failure as possible, with ongoing monitoring of the dump crest.

2:45 PM

## **Case Study: The Process Map of Mine Planning with Respect to Infrastructure and Critical Drilling Programs in a Small Underground Operation**

*A. Rai; Barrick Turquoise Ridge Inc, Winnemucca, NV*

A implementation of new mine planning software is currently underway to determine if production can be significantly and accurately planned including infrastructure and drilling programs. The primary options that were evaluated in an aggressively high grade ore body to maximize the output of the infrastructure. The purpose of this paper is to determine what mining rates, physicals, and ramp up schedule are appropriate to produce a reasonable metal plan for each alternative.

3:05 PM

## **Creative Planning to resolve Geotechnical Challenges; Experience from the Nevada Goldfields**

*R. Sharon; Geotechnical, Barrick Gold, Tuscon, AZ*

There are two basic paths to develop reliable slope designs, both of which require iterative assessments of the slope design engineer and the mine planner, if you want an optimized design. Application of minimum design criteria is industry standard for an initial highwall cut for a new project and represents a design target that might be relaxed under certain conditions for mature operations. The amount of exploration and geotechnical drilling required is to some degree subjective and depends on complexity of geological controls recognized to control the stability of the open cut. For expansion cuts at mature operations where experience can be applied, the slope designer may have the

opportunity, reinforced by motivation, to be creative, depending on economics and risk tolerance. If conditions permit, flexibility may be built into the mine plan so that low consequence changes to the development sequence can be executed in the event that instability occurs. It is to this experience-based design approach that I can share experiences from Barrick operations in Nevada.

**3:25 PM**

## **In-Pit and Ex-Pit Dump Optimisation at Boron Mine**

*T. Plote; Mine Technical Services, Rio Tinto - US Borax, Boron, CA*

The Rio Tinto Boron Mine operates as an open pit truck shovel operation. The operation has a large strip ratio which causes haulage to account for a large portion of the mine's costs. Modeling of the life of mine haulage at Boron is complex due to geotechnical restrictions that confine certain material types to dumps outside the pit shell (ex-pit) while allowing other material types to be dumped on the exposed footwall of the pit (in-pit). The modeling of haulage to the in-pit dumps can prove a challenge as the entrance point to the in-pit dumps can change over time, while the ex-pit dumps generally have a fixed dump entrance point that is used until the dump reaches capacity. This paper will explain the haulage models that were constructed at Boron in order to optimize the material haulage over the life of mine.

**3:45 PM**

## **Mine Planning and Geotechnics - The Batu Hijau Experience**

*J. Lupo<sup>1</sup>, H. Lelono<sup>2</sup>, D. Viriyatha<sup>2</sup>, Y. Adriansayah<sup>2</sup> and B. Haverland<sup>2</sup>; <sup>1</sup>Technical Services, Newmont Mining Corp, Greenwood Village, CO and <sup>2</sup>Mine Engineering, PT Newmont Nusa Tenggara, Sumbawa, Indonesia*

PT Newmont Nusa Tenggara's (PT Newmont) Batu Hijau mine is located on the island of Sumbawa in Indonesia. On an annual basis, the mine nominally produces 225 ktonnes of copper (approximately 25% of Indonesia's total copper output) and 350 koz of gold. The mine is an open pit operation with an approximate daily production of 450 to 500 ktonnes of ore and waste. The mine operation, which began in 2000, is completing its sixth phase of expansion, resulting in an open pit that is approximately 700 m deep. Additional expansion phases will result in an open pit that is over 1km deep. Over the years of operation, the open pit has experienced several large-scale slope failures and numerous smaller-scale failures, requiring changes to the mine plan in order to maintain a safe working environment. The slope failures are associated with the presence of moderate to low strength rock mass combined with strong structural controls, in the form of +25 major and secondary faults. This team effort has allowed mine planning and operations to work within the challenging conditions at the site...cont'd

## Mining & Exploration: Technology: Electronic Safety Technologies

2:00 PM • Wednesday, February 18 • 704

Chair: **J. Carr**, NIOSH, Pittsburgh, PA

2:00 PM

### Introductions

2:05 PM

### Field Evaluation of Wireless Machine Guard Monitoring System

*M. Reyes; Office of Mine Safety and Health Research, National Institute for Occupational Safety and Health, Pittsburgh, PA*

The Office of Mine Safety and Health Research is developing a machine guard monitoring system designed to mitigate machine entanglement and maintenance-related injuries prevalent in the mining industry. The system is designed to leverage wireless sensor technologies, such as radio frequency identification (RFID), in order to monitor and transmit information about a machine's guards to a remote location. The system uses magnetic and mechanical switches to detect when guards are removed. The data is then wirelessly transmitted through an off-the-shelf communication system and displayed on a web-based user interface. Field validation of the system demonstrated the functionality of the wireless technology. The system proved reliable 100% of the time when employing magnetic switches and 97% of the time when employing mechanical switches. The mechanical switch failures highlighted the environmental considerations that must be made, such as vibrations and weather, which are typical of a surface mine operations. The integration of wireless safety technologies is expected to improve the safety of miners by providing additional protections against machine guarding-related injuries.

2:25 PM

### Strata HazardAlarm - The Use of Magnetic Fields for Collision Avoidance

*T. Michaud; Strata, Sandy Springs, GA*

The HazardAlarm system was designed to meet the requirements of the WV State Law for mobile section equipment titled 36 SCR 57. Section 36-57-6 title Section Mining Equipment requires a Proximity Detection system to warn operator and persons in the area when there is a potential for collision. The HazardAlarm system utilizes the change of rate of Magnetic Field (MF) strength to determine if a PDS system is approaching a PAD or moving further away. The HazardAlarm system will attempt to determine if the two objects are closing at a speed greater than a predetermined (currently set to 2mph) and will only alert if this criteria has been exceeded. The HazardAlarm system will maintain an inner Hazard Zone that will always alarm regardless of speed. This paper will present the benefits of

HazardAlarm proximity detection for mobile pieces of equipment and how HazardAlarm and HazardAvert work together to provide a best in class mine wide proximity detection solution.

**2:45 PM**

15-083

## **Proximity Detection with Selective Machine Shutdown Built With Permissible Hardware**

*J. Ducarme, J. Carr and C. Jobes; OMSHR, NIOSH, Pittsburgh, PA*

Annually, an average of 1.2 fatalities occur in underground coal mines in the United States when a miner is struck or pinned by a remote-controlled continuous mining machine. Proximity detection technology provides a means to prevent these types of accidents by disabling all machine motion when a miner is in close proximity. The Mine Safety and Health Administration believes these systems will significantly reduce these striking and pinning accidents and is expected to finalize a regulation this year that will require their use on continuous mining machines. Researchers at the National Institute for Occupational Safety and Health have developed the intelligent Proximity Detection (iPD) system, which continuously tracks the position of miners near the machine and, disables only machine motions which could cause a pinning accident. This system, previously demonstrated using non-permissible proximity detection hardware, has now been shown to be effective when implemented using an approved system as a platform. Performance tests have shown accuracy, repeatability, and stop zone identification to be comparable to or better than the system demonstrated with non-permissible hardware.

**3:05 PM**

15-013

## **Integrating Technology: Learning from Mineworker Perceptions of Proximity Detection Systems**

*E. Haas and K. Rost; Office of Mine Safety and Health Research, National Institute for Occupational Safety and Health, Pittsburgh, PA*

This qualitative study sought to identify: (1) changes in continuous mining machine (CMM) operators' risk perception and risk behaviors as a result of adding a proximity detection system (PDS) into their environment. To accomplish this research task, 9 CMM operators from 5 locations were interviewed. Interviews were thematically analyzed for constructs including patterns in risk perception and behavior before and after PDS integration and the process of adapting to the PDS. Operators discussed standing in the red zone less than they did before [the PDS]. However, they discussed other risky decisions they made while learning how to operate their CMM with a PDS such as cheating the technology and working faster to meet production goals. The process of relearning job tasks with technology and unintended behaviors as a result of that relearning process need to be taken into account when introducing new technology into the mine environment. The study results show an in-depth view of

mine workers' perspectives and how their job tasks and environment could be or is affected when learning how to use new technology.

**3:25 PM**

## **Improving Traffic Safety at Hecla's Greens Creek Mine**

*B. Erickson and T. Ruff; Surface Operations, Hecla Greens Creek Mining Company, Juneau, AK*

Hecla Greens Creek Mining Company won the 2013 NIOSH Mine Safety and Health Technology Innovations Award for their implementation of a GPS-based traffic awareness and collision avoidance system. The technology has been installed on all surface vehicles that use the mine's single-lane access road to help avoid accidents that involve two approaching vehicles or vehicles following too close. A simple display in the cab of each outfitted vehicle gives an indication of on-coming traffic and a voice announcement indicates the type of vehicle that is coming as far out as 300 meters. Advanced warning of approaching vehicles is increasing driver awareness, especially around blind corners and in adverse weather such as heavy fog, snow, or rain. Speeding alarms have also been implemented and are especially critical as a vehicle approaches reduced speed areas near bridges and curves. A description of the system, implementation details, and safety improvements seen since its introduction will be discussed.

**3:45 PM**

## **Private Equity for Mining Technology Development**

*L. Clark; Jolimon Global Mining Systems, Denver, CO*

A few years ago the pledge to be "innovative" and employ technology to improve competitiveness, profitability and shareholder returns was pervasive. But the commitments made when mining was booming three years ago have been scaled back or eliminated with the latest downturn in the business. With attention focused intently on operating free cash flow the longer term delivery of new technologies has fallen in some cases into a "non-core activities" category. But the challenges faced by the industry have not gone away. We still suffer from declining exploration find rates, increasing metallurgical complexity, increasing depths of burial, steeply increasing operating costs, flat safety incident rates, etc. Waxing and waning support for technology development undermines the partnerships that lead to successful incremental, step-change and breakthrough developments vital to the continued success of our business. The message to the technology OEMs is that they must be prepared to fund their own product and business development but the rewards for a technology can be very high. This paper will discuss the value of private equity funding partnerships for the niche mining technology market.

## **Mining & Exploration: Technology: Managing Global Technology and Knowledge Transfer**

**2:00 PM • Wednesday, February 18 • 707**

*Chair: S. Frimpong, Missouri University of Science & Technology, Rolla, MO*

**2:00 PM**

### **Introductions**

**2:05 PM**

### **Frontiers of Global Mining Engineering Education**

*S. Frimpong; Mining & Nuclear Engineering, Missouri University of Science & Technology, Rolla, MO*

Missouri S&T has made significant efforts to extend Mining Engineering education into several countries with extensive mineral deposits but with no baccalaureate programs in mining engineering. These countries include Afghanistan, Botswana, Dominican Republic, Indonesia, Mongolia, Peru and Saudi Arabia. The presentation will focus on the programs including curriculum and faculty development, unique challenges and opportunities, institutional capacity development, technology transfer and interactions with the local mining industry.

**2:25 PM**

### **Operator Training Must Go Beyond Levers, Petals and Dexterity**

*K. Calvert; Komatsu America Corp, Rolling Meadows, IL*

KOMTRAX, Komatsu's machine monitoring system produces data that builds a strong business case that operators must be trained to think in broader terms regarding their role in mine production. Successful operations will be staffed by operators with an "I am vital to this operation" mindset as they strive to improve their personal performance and look for ways to contribute to total team performance. Case studies will be presented showing: How machine produced data can be turned into meaningful Key Performance indicators (KPIs) that can be used to engage operators in continuous improvement.

**2:45 PM**

### **When It's Wrong - The Power of Zero Hour and Reliability Review**

*T. Barnes; Joy Global (P&H Mining Equipment), Milwaukee, WI*

Product issue resolution process, both zero hour and reliability related, are practiced in some form by manufacturers and end users of equipment to identify and fix product issues, and to maintain acceptable levels of equipment safety, reliability, and operability. Often, in the rush to quickly identify a problem

statement, perform root cause, and implement a solution, we fall short on capturing the lessons learned and documenting knowledge for future use. This paper explores how a properly designed zero hour and reliability review process with balanced metrics can maximize the benefit to an organization from both a knowledge capture perspective, and a product reliability growth perspective.

**3:05 PM**

## **Building a Sustainable Technology and Knowledge Sharing Foundation**

*S. Lawson; Newmont Mining Corporation, Greenwood Village, CO*

Newmont Mining Corporation recognizes there are many challenges facing the mining industry today. Rising operating costs, increasingly complex resources and personnel constraints are factors affecting how we operate and compete. One of the most effective ways to successfully navigate this business environment is through the effective utilization of technology and transfer of knowledge across an organization. To this end, Mr. Lawson will present Newmont's approach to building a sustainable technology and knowledge sharing foundation. Through developing robust Technical Foundations, utilizing standardized systems and processes and establishing global Communities of Practice, Newmont's Technical Services team has formed a seamless and engaged technical community able to thrive in a complex business environment and deliver measurable value across all cycles.

**3:25 PM**

## **Global Mining**

*B. Galli; Peabody Energy, St. Louis, MO*

Abstract TBA

## **Mining & Exploration: Technology: Predictive Maintenance: Technology and Practice**

**2:00 PM • Wednesday, February 18 • 705**

*Chairs: M. Lewis<sup>1</sup>, Modular Mining Systems, Tucson, AZ  
G. Lanz<sup>2</sup>, Modular Mining Systems, Inc., Tucson, AZ*

**2:00 PM**

## **Introductions**

**2:05 PM**

## **Hibbing Taconite's Predictive Maintenance Program**

*D. Lerick; Hibbing Taconite Company, Hibbing, MN*

Successful capital-intensive industries, such as mining, have realized that a highly efficient and productive maintenance organization will increase shareholder and stakeholder value. One of the methods of increasing equipment uptime to provide this value has been to move the maintenance program from a reactive maintenance program to a predictive maintenance program. This presentation will capture the growth, the setbacks, and the successes of the use of predictive maintenance on mining equipment in both the open pit mining and material processing applications. Topics covered will include vibration analysis, the lubrication program, oil analysis, infrared thermal imaging, and will touch on ultrasound testing, non-destructive testing, and motor circuit analysis.

**2:25 PM**

## **The Role of Big Data in Real-Time Equipment Condition Monitoring**

*S. Van Wegen; Marketing, Modular Mining Systems, Inc, Tucson, AZ*

With an increasing amount of online condition monitoring data available for mining equipment, the concept of "Big Data" has emerged in maintenance organizations and customer appetite for this data is growing at a fierce rate. This presentation will discuss the current and future trends in data storage and analytics, techniques for optimum data collection, and conversion of the data into actions that generate value. It will discuss how to apply rules to collect this data under conditions that may highlight early-onset failures, and describe how to analyze the data to determine indicators of the impending failure mode. Case study results will be used to show that early onset conditions, often present prior to failures, can be exposed by collecting the right data under the right conditions. When these indicators are determined, the logic to detect these indicators in real time can be built into the equipment health monitoring system. This can lead to failures being detected weeks in advance, and the appropriate actions put in place to intervene in a proactive manner.

**2:45 PM**

## **Online Lubrication Monitoring in Mining Applications**

*R. Brewer and T. Marvin; Poseidon Systems, Rochester, NY*

Conventional lubrication management practices utilize offline sampling and analysis methods to detect lubrication degradation and developing equipment faults. In order to maximize the value of an oil analysis program, Poseidon Systems has developed and deployed online Fluid Quality Monitoring Systems on a variety of mining equipment. These systems consist of a suite of sensors designed to monitor a variety of lubricant properties. The sensor package used in these systems is custom packaged to the needs of the application. As an example, some of these systems have included viscometers, metallic debris monitors (ferrous and non-ferrous particle counters), oil quality monitors,

and moisture-in-oil sensors. In addition to monitoring the lubricant itself, the system also provides warnings about engine and vehicle health overall. Faults such as coolant leaks, reburn system failures, and stuck injectors can be detected in real time. This presentation will discuss the applicability of each sensor to various monitoring situations, the benefits achieved, and the some of the sensing techniques utilized. Example data and case studies of several tests and deployments will also be discussed.

**3:05 PM**

## **Using Context Based Condition Management to Enable Predictive Maintenance**

*J. Fillion<sup>1</sup> and F. Mielli<sup>2</sup>; <sup>1</sup>Schneider Electric, Foxboro, MA and <sup>2</sup>Schneider Electric, Alpharetta, GA*

Although the benefits of predictive maintenance are widely accepted, the proportion of companies taking full advantage of the approach remains relatively small. For many potential users, the complexity and cost of many condition monitoring systems remains a significant obstacle. The Mining industry is challenged to find a way of solving this problem, and have an holistic approach to avoid the shortcomings of traditional methods, and, importantly it has to avoid the heavy setup and analysis burden on busy maintenance staff. The paper will discuss the context based condition management approach with case studies showing its effectiveness in preventative maintenance regimes

# INDEX: AUTHORS & CHAIRS

- Abbott, David . . . . . 38, 141  
Abrams, Adele L. . . . . 223  
Achelpohl, Eric . . . . . 155  
Ackah, Louis . . . . . 74  
Adiguzel, Deniz . . . . . 89  
Adriansayah, Yan . . . . . 289  
Adsero, Richard . . . . . 132  
Aften, Carl . . . . . 237  
Agasty, Amit . . . . . 221  
Agioutantis, Zacharias . . . 159  
Ahnhut, Adam . . . . . 120  
Akkaya, Ufuk G. . . . . 89  
Aksoy, Bayram . . . . . 105  
Alagha, Lana . . . . . 22  
Albert, Mitch . . . . . 211  
Alch, Timothy . . . . . 44  
Alcorn, Derek . . . . . 180  
Alegria, Bernardino . . . . . 105  
Alexander, Dan . . . . . 77, 268  
Alford, Chris . . . . . 56  
Allen, Lawrence . . . . . 203  
Amante, Joseph . . . . . 213  
Amin, Ashok . . . . . 17  
Anani, Angelina K. . . 155, 265  
Anderson, Corby G. . 174, 180  
Anderson, Dan A. . . . . 232  
Anderson, Kris . . . . . 170  
Anderson, Melissa . . . . . 272  
Anderson, Scot . . . . . 253  
Andres, Josh . . . . . 182  
Andriatno, Dody . . . . . 266  
Annandale, Deon . . . . . 176  
Annandale, George W. . . . 91  
Anstine, Dave . . . . . 214  
Aouad, Nassib S. . . . . 221  
Aquino, Benigno . . . . . 280  
Araujo, Darlan B. . . . . 251  
Arinaitwe, Esau . . . . . 245  
Arista, Brian R. . . . . 96  
Armstrong, Kent . . . . . 145  
Armstrong, Michael . . . . . 125  
Arndt, James L. . . . . 33  
Arnold, Tim . . . . . 225  
Arnold, Barb . . . . . 20, 73, 224  
Arthur, Francis A. . . . . 76  
Asante, William . . . . . 262  
Ashley, Brett A. . . . . 64  
Askari-Nasab, Hooman . . 200  
Austin, Bonnie . . . . . 50  
Awuah-Offei, Kwame . 39, 186, 265  
Azman, Amanda S. . . . . 165  
Back, Steven F. . . . . 26  
Badger, Rachel . . . . . 231  
Bagby, William C. . . . . 140  
Bagherieh, Amir H. . . . . 76  
Bahrami, Davood . . . 259, 262, 263  
Bailey, Dick . . . . . 71  
Baker, Mark R. . 35, 37, 92, 94, 104, 181, 276  
Baker, Tyson . . . . . 244  
Bakhsh, Kamran J. . . . . 204  
Ball, Brandon R. . . . . 93  
Bandopadhyay, Sukumar . 219, 273, 274  
Banerjee, Kashi . . . . . 232  
Banerjee, Tuhin . . . . . 180  
Barickman, Ruby . . . . . 186  
Barkley, Matthew D. . . . . 228  
Barnard, Chase . . . . . 129  
Barnes, Tom . . . . . 293  
Barnum, Heather . . . . . 229  
Barone, Teresa . . . . . 270  
Barrios, Godofredo . . . . . 280  
Barron, Tania . . . . . 161  
Bartlett, Mark . . . . . 134, 197  
Barton, Scott . . . . . 162  
Basavarajappa, Manjunath . . . 107, 113, 246  
Bascetin, Atac . . . . . 89  
Bascur, Osvaldo A. . . 123, 178  
Batistella, Marcos . . . . . 166  
Bays, James . . . . . 37  
Bealko, Susan . . . . . 146  
Beck, Timothy W. . . . 149, 275  
Becker, Sebastian . . . . . 174  
Beerbower, David A. . . . . 146  
Behrens, Kai . . . . . 243

# INDEX: AUTHORS & CHAIRS

- Bender, Jack . . . . . 184  
Benowitz, Scott . . . . . 93, 162  
Benson, Mary Ellen . . . . . 43  
Bentley, Stu . . . . . 275  
Benton, Donavan . . . . . 127  
Berg, Jan . . . . . 68  
Bergholm, Katy . . . . . 36  
Bernal, Gonzalo . . . . . 97, 98  
Bertrand, Frank J. . . . . 140  
Besler, Dave . . . . . 143, 150  
Beverage, Laura . . . . . 7  
Bhagwat, Anand . . . . . 213, 23  
Bhambhani, Tarun . . . . . 240  
Bhattacharyya, Sekhar . . . . . 81  
Bhowmick, Taraprasad . . . 219,  
274  
Billin, Samuel J. . . . . 162, 235  
Bingham, Nancy . . . . . 29, 46  
Black, Zachary. . . . . 250, 251  
Blackley, David . . . . . 207  
Blalock, Ed . . . . . 267, 268  
Blanco, Edgar . . . . . 96, 97  
BoBo, Tom . . . . . 178  
Bogin, Greg 28, 220, 222, 274  
Boisvert, Jeff B. . . . . 252  
Bommer, Kathleen M. . . . . 71  
Bon, Carlos S. . . . . 240  
Boskovic, Sasha . . . . . 184  
Bottjer, David . . . . . 171  
Botz, Michael . . . . . 108  
Boyce, Thomas E. . . . . 164  
Brackpool, Carl . . . . . 200  
Braden, Lusk . . . . . 78  
Brashear, Kyle . . . . . 213, 222  
Bratton, Robert . . . . . 74  
Braun, Kurt . . . . . 137  
Brewer, Ryan C. . . . . 295  
Brickey, Andrea . . . . . 58  
Briggs, Amy . . . . . 189  
Brits, Chris . . . . . 176  
Brokering, Robert D. . . . . 258  
Brown, Jacob D. . . . . 117  
Brown, Jeremy H. . . . . 199  
Brown, Richard . . . . . 166  
Brune, Jurgen . . . . . 26, 28, 204,  
209, 220, 222, 272, 274  
Bryant, Peter . . . . . 10, 69  
Buchan, Gary . . . . . 81, 224  
Buckley, Jessica . . . . . 209  
Buman, Arkady . . . . . 243  
Burchett, Todd . . . . . 16  
Burgess, Jeff . . . . . 205  
Burton, Holly . . . . . 190  
Bush, Dave . . . . . 267, 268  
Byles, Kirk . . . . . 66  
Caldwell, Keri L. . . . . 243, 244  
Calizaya, Felipe . . . 27, 28, 85,  
220  
Calvert, Ken . . . . . 293  
Camm, Thomas . . . . . 49  
Campbell, Christopher 52, 122  
Campoli, Alan A. . . . . 223  
Cantero, Carlos . . . . . 261  
Cantin, Stéphane . . . . . 198  
Carlile, David . . . . . 6  
Carlson, Erik . . . . . 159  
Carpenter, Karena . . . . . 263  
Carr, Jacob . . . . . 147, 290, 291  
Carter, Jeannine . . . . . 29  
Carvalho, Monica . . . . . 160  
Carver, John . . . . . 8  
Cassidy, Patrick . . . . . 171  
Castaños, Pablo . . . . . 230  
Castner, Michael J. . . . . 75  
Causey, A. . . . . 265  
Cedron, Mario . . . . . 173  
Cervinka, Alexandre . . . . . 198  
Chambers, Derrick . . . . . 129  
Chambers, Paul . . . . . 268  
Chancellor, Graham G. 59, 266  
Chapman, Andrew . . . 60, 134  
Chatterjee, Snehamoy . . . . 39  
Chen, Xiuzhen . . . . . 106  
Chow, Edmond . . . . . 70  
Churr, Andy . . . . . 31, 158  
Clancy, Kelly . . . . . 269  
Clark, Curtis . . . . . 127  
Clark, Larry . . . . . 197, 292  
Clarke, Ronald . . . . . 158

# INDEX: AUTHORS & CHAIRS

- Clausen, Elisabeth . . . 149, 221  
Cleason, James L. . . . . 71  
Coffin, Eric . . . . . 288  
Cohen, Ken . . . . . 267  
Colinet, Jay . . . . 148, 269, 270  
Comer, Robert . . . . . 7  
Comi, Thomas J. . . . . 175  
Conger, Red . . . . . 10  
Conley, Brittany . . . . . 83  
Connelly, Damian . . . . . 109  
Conrad, William J. . . . . 75  
Conrad, Paul . . . 153, 196, 285  
Cook, Robert . . . . . 198, 278  
Cooper, Cy . . . . . 186  
Cooper, Roger . . . . . 251  
Cooper, Allen . . . . . 90  
Cordani, Ben . . . . . 29  
Cornman, Jacob . . . . . 144  
Corsetti, Frank . . . . . 171  
Cossio, Claudio . . . . . 266  
Costa, Marcelo . . . . . 246  
Cotten, Steven A. . . . . 271  
Cox, Benjamin . . . . . 45  
Crawford, Diane . . . . . 91  
Cross, Michael . . . . . 182  
Croteau, Serge . . . . . 198  
Cui, Wenyan . . . . . 183  
Curfman, Christopher . . . . . 10  
Curtiss, Brian . . . . . 242  
Dagdelen, Kadri . . . . 201, 204  
Daniels, Eric B. . . . . 252  
Danko, George . 259, 262, 263  
Danquah, Frank . . . . . 172  
Dase, Joe . . . . . 59  
Davenport, Jenny . . . . . 88  
Davies, John . . . . . 285  
Davis, Graham A. . . . 138, 188  
Davis, Greg . . . . . 36  
Davis, R J. . . . . 236  
Dawson, Todd . . . . . 117  
Delgado-Jimenez, Alejandro . . . . . 228  
DeMarco, Mike . . . . . 51  
Deng, Jun . . . . . 21, 85  
Dennis, Michael . . . . 174, 238  
Dereski, Sean R. . . . . 59  
Derycke, Steven . . . . . 213  
Dessureault, Sean . . . 45, 122, 124, 166, 187, 196, 199, 287  
Deutsch, Clayton V. . . . . 252  
Deutsch, Matthew V. . . . . 123  
Dhyne, Brian . . . . . 258  
Diaz, Manuel . . . . . 100  
Diaz, Ronald . . . . . 100  
Diaz, Richard . . . . . 117  
Dietze, Anne . . . . . 67, 201  
Dindarloo, Saeid R. . . 197, 215  
Dipas, Carlos . . . . . 265  
Dirscherl, Christian . . . . . 240  
Djoboulian, Gregory . . . . . 40  
Dobson, Steven . . . . . 96  
Doerr, Donald . . . . . 267, 268  
Doig, Patrick . . . . . 151, 152  
Dolsak, Wolfgang . . . . . 59  
dong, Wang S. . . . . 80  
Doubleday, Timothy . . . . . 103  
Dougherty, Heather . . 26, 213, 222, 260  
Dozortsev, Vladimir . . . . . 234  
Drabble, Michael . . . . . 44  
Druckenmiller, Michael . . . 238  
Ducarme, Joseph . . . . . 291  
Dunwoody, Paul . . . . . 143  
Durfee, Dave . . . . . 59  
Eades, Robert . . . . . 270  
Easton, Jeff . . . . . 95, 278  
Edington, Dwaine H. . . . . 88  
Edwards, Ross . . . . . 181  
Eger, Paul . . . . . 35, 87  
Eggert, Derek . . . . . 95  
Eisele, Timothy C. . . . . 108  
Elgert, Lawrence . . . . . 54  
Elifrits, C. Dale . . . . . 45  
Ellenberger, John. . . . . 81  
Ellis, Trevor R. . . . . 139  
Emmerich, Nathan . . . . . 184  
Erfourth, Bethany . . . 181, 275  
Erickson, Brian . . . . . 292  
Erkayaoglu, Mustafa . . . . . 124  
Eslambolchi, S. Safa . . . . . 153

# INDEX: AUTHORS & CHAIRS

Esterhuizen, Gabriel S. . . . .	81	Garcia, Jesus . . . . .	55
Evans, Derek . . . . .	37	Gardner, James S. . . . .	271
Evans, Michael L. . . . .	126	Gardner, Katie . . . . .	257
Everly, Colt . . . . .	185	Garska, Mike . . . . .	45
Ezell, Derrell D. . . . .	154	Gavrilovic, Mick . . . . .	99, 172
Fahrman, Ben . . . . .	283	Gbadam, Erik . . . . .	76
Fallow, Aaron . . . . .	96, 106	Ge, Maochen . . . . .	76
Fan, Maoming . . . . .	96	George, David . . . . .	45, 131
Fanara, Andrew . . . . .	45	George, P. . . . .	247
Farah, Anis . . . . .	125	Gernand, Jeremy M. . . . .	254
Farbakhsh, Faraz . . . . .	74	Ghosh, Tathagata . . . . .	20, 22, 73
Farinato, Raymond . . . . .	241	Giblett, Aidan . . . . .	174, 238
Farrell, Sean C. . . . .	60	Gibson, Jake . . . . .	20
Fecht, Steven . . . . .	229	Giese, Ellen C. . . . .	109
Fein, M. . . . .	202	Gilbert, David . . . . .	226, 277
Feledi, Koziba . . . . .	86	Gilbert, Rick . . . . .	32, 130
Felts, Tim . . . . .	17	Gillies, Stewart . . . . .	27, 84, 147
Feng, Zhao B. . . . .	80	Gilliland, Ellen S. . . . .	18
Fernández Romero, Fernando . . . . .	178	Gillow, Jeff . . . . .	157
Fernando, Rohan . . . . .	143, 144, 145, 267, 268	Gilmore, Richard C. . . . .	28, 220, 222, 274
Fietz, Nina B. . . . .	78	Giocomin, Hannah . . . . .	217
Fillion, Joseph . . . . .	296	Giraldo, Luis . . . . .	271
Flores, Daniel . . . . .	256	Glaser, Peter . . . . .	7
Flowers, Jim . . . . .	43	Godoy, Marcelo . . . . .	202
Forbort, Jon . . . . .	38, 228	Goertz, Benjamin . . . . .	204
Forman, Jared . . . . .	125	Gonzalez, Eric . . . . .	123
Frank, Gabriel . . . . .	217	Gonzalez, Jorge . . . . .	266
Franklin, Martin M. . . . .	194	Goodfellow, Ryan C. . . . .	201
Fredriksson, Henri . . . . .	185	Gow, Robert N. . . . .	249
Free, Michael . . . . .	184	Gozdor, Matthew J. . . . .	34
Freeman, Leigh . . . . .	48	Graber, Shaun . . . . .	266
Fretheim, Erika . . . . .	66	Gray, Richard E. . . . .	152
Frimpong, Samuel . . . . .	293	Gray, Thomas A. . . . .	217
Fuerstenau, Douglas W. . . . .	110	Grayson, R. Larry . . . . .	153
Furlong, Karen . . . . .	233	Greer, Briana . . . . .	156, 157
Furniss, Matt . . . . .	65	Griffin, Adam . . . . .	38
Fytas, Kostas . . . . .	121	Grubb, John . . . . .	28, 220, 222, 274
Gabeva, Deliana A. . . . .	34	Gu, Zhengxing (James) . . . . .	106
Gagliano, Ryan L. . . . .	39	Guedes, Chris . . . . .	36
Galarza, Luis . . . . .	239	Guo, Lijie . . . . .	167
Galli, Bryan . . . . .	10, 294	Gupta, Vishal . . . . .	235
Gant, Shane S. . . . .	166, 287	Gusek, James J. . . . .	36
Garcia, Dante . . . . .	105	Gustafson, Anna . . . . .	192
		Gustavson, John B. . . . .	210

# INDEX: AUTHORS & CHAIRS

- Guzman, Gilmar . . . . . 108  
Haas, Emily J. . . . . 291  
Haas, Joe . . . . . 127  
Haggerty, Michael 1. . . 69, 170  
Haghighat, Ali 27, . . . . . 222  
Hahn, Stuart . . . . . 190  
Hajastron, Michael . . . . . 50  
Halatchev, Rossen A. . . . . 191  
Halderman, Heather . . . . . 90  
Halhead, Michael . . . 123, 178  
Halldin, Cara N. . . . . 207  
Haller, Travis S. . . . . 193  
Hallman, David . . . . . 154  
Halt, Joseph . . . . . 241  
Hammond, David R. . . . . 188  
Hammond, Tony . . . . . 169  
Hanna, Braden . . . . . 156  
Hanselaer, Thomas . . . . . 213  
Hansen, Heather . . . . . 238  
Hanson, Brad . . . . . 82  
Hanson, Kirk . . . . . 55  
Hardin, Mark P. . . . . 231  
Harmon, Angie . . . . . 47  
Harris, Douglas J. . . . 114, 276  
Harris, Leonard . . . . . 174  
Hart, Brad . . . . . 33  
Hart, Mitchell . . . . . 36  
Harteis, Samuel P. . . . . 79  
Haselhuhn, Howard . . . . 279  
Hasenfus, Greg . . . . . 25  
Haughey, James . . . . . 216  
Haverland, Brian . . . . . 289  
Hawkins, Mark . . . . . 71  
Hay, Michael . . . . . 34, 36, 157  
Haynes, John . . . . . 92  
Hearn, Steve . . . . . 184  
Heath, Gail . . . . . 92  
Hebblewhite, Bruce . . 83, 102,  
152, 273  
Heckman, Christopher R. . 183  
Helbig, Josh . . . . . 216  
Helgen, Steve . . . . . 157  
Henderson, Nicole R. . . . 272  
Henn, Ray . . . . . 136, 207  
Herman, Victoria . . . . . 177  
Hermanson, Tawnya . . . . 125  
Hermülheim, Walter . . . . 272  
Herrera, Juan M. . . . . 124  
Herrmann, Luisa . . . . . 93  
Hethmon, Thomas . . . . . 206  
Highsmith, Patrick . . . . . 48  
Hillard, Patrick . . . . . 119  
Hindle, Kim . . . . . 194  
Hitzman, Murray . . . . . 48  
Hodgkinson, Andrew. . . . . 94  
Holder, Lee . . . . . 91  
Holmes, Sarah . . . . . 178  
Holsinger, Kent . . . . . 7  
Honaker, Rick . . 21, 22, 45, 78,  
277, 278  
Housley, Brett . . . . . 163, 278  
Hu, Yuehua . . . . . 106  
Huang, Hsin-Hsuin . . . . . 249  
Huang, Kaiwu . . . . . 113, 246  
Huang, Qingqing . . . . . 78  
Hudson, Barry . . . . . 10  
Hughes, Greg D. . . . . 249  
Humphrey, James . . . . . 61  
Huttu, Kyösti . . . . . 57  
Hutzler, Brent . . . . . 183, 186  
Iannacchione, Anthony T. . 217  
Ibarra, Virginia . . . . . 195  
Ibrado, Art S. . . . . 110  
Ingle, John H. . . . . 189  
Inglis, Richard . . . . . 203  
Isaaks, Edward . . . . . 252  
Iverson, Steve . . . . . 25, 127  
James, Patrick. . 35, 38, 92, 94,  
104, 115, 181, 276  
Janisko, Sam J. . . . . 270  
Jarvie Eggart, Michelle. 86, 158  
Javier, Mauro . . . . . 225  
Jennings, Katherine. . . . . 120  
Jespersen, Mads . . . . . 244  
Jeter, T Scott . . . . . 222  
Jewbali, Arja . . . . . 203  
Jewell, Michael . . . . . 253  
Jha, Ankit. . . . . 27  
Jiang, Hua . . . . . 219  
Jiang, Xinkai . . . . . 240

# INDEX: AUTHORS & CHAIRS

- Jingyu, Zhao . . . . . 215
- Jobes, Chris . . . . . 147, 291
- Johnson, Jeffery . . . . . 127
- Johnson, Jeffrey . . . . . 25, 278
- Johnson, Jeremy W. . . . . 287
- Johnson, Jerold
- Johnson, Lane A. . . . . 226
- Johnson, Robert J. . . . . 165
- Jones, Tristan . . . . . 127
- Jong, Edmund . . 83, 147, 222
- Joshi, Devendra . . . . . 39
- Joslyn, Andrew P. . . . . 91
- Journet, Nicholas . . . . . 255
- Joy, Gerald J. . . . . 148
- Jun, Deng . . . . . 79, 215
- Kahraman, Muhammet  
Mustafa . . . . . 199
- Kallu, Rajagopala. . . 128, 129,  
284
- Karmis, Michael . . 18, 48, 159
- Kaufman, Garrison . . . . . 7
- Kaushik, Sarthak . . . 114, 180
- Kawahata, Kazuhiro . . . . . 202
- Kawatra, S. K. . . . . 241, 279
- Kearney, Christie . 86, 88, 158
- Kecojevic, Vladislav . . . . . 102
- Keles, Cidgem . . . . . 150
- Kellie, Bob . . . . . 16
- Kellar, Jon . . . . . 45
- Kelly, Bob . . . . . 116
- Kemeny, John . . . . . 178
- Kendall, William . . . . 210, 218
- Khan, Muhammad U. . . . . 84
- Khatibi, Simin . . . . . 22
- Kim, Eunhye . . . . . 281, 283
- Kimball, Doug . . . . . 268
- King, Dale . . . . . 23
- King, Mike . . . . . 9
- Kirsch, Philipp . . . . . 83, 273
- Klug, David . . . . . 136, 207
- Knight, Michael A. . . . . 41
- Knobloch, Timothy . . 139, 209
- Knorr, Brian R. . . . . 177
- Knowles, Jim . . . . . 146
- Koca, Matthew J. . . . . 269
- Kochunarayanan, Parvathy 34
- Kocsis, Karoly . . . . . 260, 263
- Kofsky Wofford,  
Stephanie A. . . . . 246
- Kogel, Jessica . . . . . 29
- Korpi, Mary B. . . . . 46
- Kosloski, Katie . . . . . 39
- Kozoriz, Shane . . . . . 122
- Kramer, Stacy L. . . . . 115
- Kratochvil, David . . . . . 233
- Kressner, Martin . . . . . 126
- Kretschmann, Jürgen 173, 272
- Krug, Garrett . . . . . 265
- Kudlawiec, Robert . . . . . 216
- Kumar, Ajay . . . . . 133
- Kumar, Ashish R. . . . . 148
- Kurth, Henry . . . . . 16
- LaBranche, Nikky . . 151 , 223,  
224
- Laflamme, Marcel . . . . . 121
- Lahm, Andres . . . . . 26
- Laitos, Jan . . . . . 8
- Lajoie, Louise . . . . . 62, 63
- Lambrych, Kevin . . . . . 179
- Laney, A. Scott . . . . . 207
- Laney, Debbie . . . . . 111
- Lange, Cary . . . . . 282
- Langefeld, Oliver . . . . . 149
- Lanz, Gregory . . . . . 294
- Lapworth, Andy . . . . . 132
- Larsen, John . . . . . 193
- Larson, Mark K. . . . . 80
- Larson, Michael . . . . . 176
- Lavigne, Jamie . . . . . 60
- Lawson, Scott . . . . . 294
- Learmont, R. D. . . . . 230
- Lechner, Carime . . . . . 227
- Lee, Edward . . . . . 44
- Lee, Vivien . . . . . 205
- Lee, Jaehoen . . . . . 108
- Lelinski, Dariusz . . . . . 244
- Lelono, Hemiel . . . . . 289
- Leone, Gaston . . . . . 36
- Lerick, Daniel . . . . . 295
- Levesque, Michelle . . . . . 160

# INDEX: AUTHORS & CHAIRS

- Lewis, Jesse . . . . . 88  
Lewis, Michael . . . . . 294  
Li, Bei . . . . . 79  
Li, Bowen . . . . . 166, 167, 169  
Li, Mingfeng . . . . . 165  
Li, Mingming . . . . . 77  
Li, Xiaoting . . . . . 82  
Li, Zhenbao . . . . . 21  
Lifton, Gareth M. . . . . 52  
Lin, Chen-Luh . . . . . 112, 235, 242  
Linton, Libbie. . . . . 278  
Lipps, William . . . . . 68  
Littau, Sally . . . . . 205  
Littlejohn, Patrick. . . . . 233  
Litton, Charles D. . . . . 79  
Liu, Bo . . . . . 168  
Liu, Guangsheng . . . . . 167  
Liu, Jay M. . . . . 182  
Liu, Jing . . . . . 235  
Liu, Runqing . . . . . 106  
Liu, Weiping. . . . . 241  
Liu, Zuohua . . . . . 279  
Loke, Gary R. . . . . 140  
Lombardi, John A. . . . . 95  
Lonergan, James E. . . . . 57  
Long, Suzanna . . . . . 186  
Longacre, John 1. . . . . 80  
Loomis, Ian . . . . . 260  
Lopez, Oscar . . . . . 233  
Lopez-Cuesta, José-Marie 166  
Loring, David M. . . . . 258  
Louk, Andrew K. . . . . 18  
Lozier, Jim . . . . . 94  
Lu, Chao . . . . . 262  
Lu, Jun. . . . . 25  
Lucas, Julie . . . . . 229  
Lundin, Anna . . . . . 18, 160, 161  
Luo, Yi . . . . . 77, 219  
Lupo, John . . . . . 289  
Lurie, Martin . . . . . 127, 142  
Luttrell, Gerald . . . . . 73, 74, 278  
Lutz, Eric A. . . . . 205  
Lutz, Tim . . . . . 147  
Luxbacher, Kray. . . . . 83, 213, 218,  
222, 272, 273  
Luyima, Alex . . . . . 183  
Ma, Li . . . . . 21  
Ma, Xu . . . . . 283  
Mack, John . . . . . 87  
Mahdi Badiozamani,  
Mohammad . . . . . 200  
Mahmoodabadi, Majid . . . . . 278  
Mahmoudkhani, Amir . . . . . 41, 42  
Maki, Jon . . . . . 246  
Malhotra, Deepak 99, 101, 172  
Mangold, Mace . . . . . 90  
Manolopoulos, Helen . . . . . 157  
Mansanti, John . . . . . 45  
Marin, Jose . . . . . 240  
Marinucci, Julie . . . . . 230  
Marril, Rolan . . . . . 236  
Martell, Peter . . . . . 161  
Marti, Andrew D. . . . . 72  
Martikainen, Mika A. . . . . 164  
Martin, Andrea K. . . . . 227  
Martin, Lewis A. . . . . 25  
Martin, Peter G. . . . . 53  
Martins, Ken . . . . . 232  
Marts, Jonathan . . . . . 28, 220, 222,  
274  
Marvin, Tim . . . . . 295  
Matkovich, Carolyn . . . . . 88  
Matson, Kelly . . . . . 88  
Matthews, Thomas C. . . . . 252  
Matthews, Vincent . . . . . 239, 240  
Mattsson, Toni . . . . . 112  
Maulana, Andryan . . . . . 266  
Maunder, Darryl W. . . . . 154  
Mazumdar, Joy . . . . . 72  
McCallum, Amy . . . . . 186  
McCallum, Tyler . . . . . 186  
McCandless, Jordan . . . . . 47  
McCarter, Michael . . . . . 24, 129  
McCray, Michelle . . . . . 42  
Mcurdy, Karr . . . . . 6  
McDaniel, Sean . . . . . 204  
McDoniel, Darin . . . . . 120  
McGinn, Aj . . . . . 208  
McHale, Karen . . . . . 162  
McKeon, Casey . . . . . 225

# INDEX: AUTHORS & CHAIRS

- McKnight, Ben ..... 256  
McLemore, Virginia T. .... 118  
McMillan, Ralph ..... 51  
McNair, Harold ..... 222  
Meadows, David 104, 105, 178  
Meagher, Conor ..... 202  
Medina, Juan F. .... 229  
Menzer, Fred ..... 5  
Mercier, Simon ..... 62, 63  
Merrill, Steven ..... 97  
Michael, Peter R. .... 87  
Michaud, Tom ..... 217, 290  
Mielli, Fabio ... 111, 122, 123,  
198, 236, 296  
Mierzejewski, Marek ..... 93  
Milavec, Pamela ..... 217  
Millar, Dean L. .... 160  
Miller, Jan D. ... 111, 112, 235,  
241, 242  
Miller, Tim ..... 81  
Mills, Mark ..... 53  
Mills, Kimberly ..... 240  
Miranda, Paul ..... 179  
Mischo, Helmut ... 26 61, 67,  
101, 174, 182, 260  
Miscovic, Ilija ..... 20  
Miskovic, Sanja 107, 113, 243,  
246, 278  
Mitra, Rudrajit ..... 83, 273  
Moats, Michael S. .... 183  
Moberly, Michael ..... 7  
Mohanty, Manoj ..... 74  
Mohanty, Samrat ..... 24  
Moharana, Abinash ..... 57  
Molatlhegi, Ontlametse K. . 22  
Moll, William ..... 168  
Momayez, Moe ..... 92, 261  
Montiel Petro, Luis ..... 203  
Moore, Charlie ..... 173  
Moore, Louise .. 246, 253, 254  
Moore, Lucas R. .... 96, 106,  
Moran, Patricia ..... 157  
More O'Ferrall, Gregory C. 194  
Morgan, Virginia ..... 230  
Moritz, Edwin C. .... 211  
Morrell, Steve ..... 175  
Mortensen, Eric R. .... 281  
Motes, Erin D. .... 69  
Mottola, Laura ..... 135  
Mucho, Romulo ..... 101  
Mudd, Debbie ..... 48  
Muddasani, Srikanth Reddy ..  
93, 232  
Mueller, Dave ..... 72  
Mueller, Toni ..... 101  
Munjal, Pritish ..... 19  
Munroe, Erik ..... 118  
Munson, Richard ..... 142  
Murphy, Michael M. .... 81  
Naeimipour, Ali ..... 264  
Nagaraj, D.r. .... 241, 245  
Nagel, Harry ..... 155  
Neff, Thomas ..... 26  
Nelson, Michael G. . 27, 28, 81  
Nelson, Priscilla ..... 6  
Neumann, Kai Werner .... 68  
Newcomen, Warren ..... 288  
Newman, Alexandra S. ... 152  
Newman, David ..... 23  
Newman, Steven ..... 254  
Nicholson, Andrew D. .... 157  
Nielsen, Barbara ..... 90, 91  
Nienhaus, Karl ..... 68, 78  
Nieto, Antonio ..... 58, 264  
Nikam, V. .... 247  
Nitschke, Axel G. .... 59  
Noble, Aaron ..... 73, 74, 77  
Noppe, Mark A. .... 151  
Novak, Thomas ..... 148  
Ochsner, Robert ..... 82, 136  
O'Driscoll, Mike J. .... 42  
Ofiara, Dennis ..... 136  
Ohlheiser, Todd ..... 5  
Oliveira, Débora M. .... 109  
Oliver, James A. .... 71  
Olmstead, Joshua ..... 5  
Olson, Tim ..... 243  
Orf, Dianna ..... 9  
Organiscak, John A. . 149, 275

# INDEX: AUTHORS & CHAIRS

Osanloo, Morteza . . . . .	197	Piercey, Steve . . . . .	59
Osouli, Abdolreza . . . . .	282	Pirkle, Fredric L. . . . .	140
Ossenbühl, Ingo . . . . .	59	Plocus, Van . . . . .	36
Ostberg, Nick . . . . .	103	Plote, Trevor . . . . .	289
Ostoyich, Ryan . . . . .	209	Pohl, Matthias . . . . .	126
Oswald, Glen . . . . .	236	Pollock, Douglas E. . . . .	149
Otazaghine, Belkacem . . . . .	166	Pomeroy, Chelsea . . . . .	26
Owen, Jonathan . . . . .	42	Pool, Rod . . . . .	61
Palladino, Richard . . . . .	136	Porras, Laura . . . . .	137
Pan, Lei . . . . .	107	Porter, Valerie . . . . .	231
Pancher, Jeffrey M. . . . .	248	Potts, J. D. . . . .	149
Pankow, Kris . . . . .	129	Poulton, Mary . . . . .	48, 92, 130
Paraszczak, Jacek . . . . .	121, 192	Prakash, Prakhar . . . . .	95
Pariseau, William G. . . . .	82	Preece, Dale S. . . . .	257
Park, Seungwoo . . . . .	113	Prestamo, Arturo . . . . .	100
Parkinson, Cory. . . . .	96	Price, Adam . . . . .	196
Parr, Adam . . . . .	39	Pruett, Bob . . . . .	41
Partey, Frederick K. . . . .	36	Pugh, Joe G. . . . .	146
Pascoe, Christopher . . . . .	193	Purchon, Simon S. . . . .	51
Pastor, Samson . . . . .	190	Quillen, Jared . . . . .	88
Patra, Partha . . . . .	131	Quinlan, Scott . . . . .	217
Patts, Justin . . . . .	270	Rademan, Johan M. . . . .	53
Patts, Larry D. . . . .	270	Rader, Geoff . . . . .	38
Pawar, Gorakh . . . . .	85	Rahal, Ken . . . . .	243
Pecard, Dan . . . . .	243	Rahn, Jenessa . . . . .	55
Peng, Felicia F. . . . .	245	Rai, Arunkumar R. . . . .	53, 84, 258, 288
Peng, Sihong . . . . .	125	Raj, Kumar V. . . . .	219, 273, 274
Peng, Tongjiang . . . . .	168	Rajamani, Raj . . . . .	177
Peralta, Edwin R. . . . .	56, 58	Rajapakse, Suresh . . . . .	116
Pereyra, Julie . . . . .	51	Ramani, Raja V. . . . .	273
Perez, Benito . . . . .	124, 187	Ramirez, Mark . . . . .	260
Perin, Dino . . . . .	176	Ransom, Megan . . . . .	256
Perkins, Myles . . . . .	157	Rapp, Soenke . . . . .	264
Perkins, David . . . . .	278	Rashidi, Samira . . . . .	177
Perlmutter, Barry A. . . . .	275	Rauch, Thomas . . . . .	65
Perry, Kyle . . . . .	78, 127, 270	Ravishankar, Sa . . . . .	235
Perry, Robert . . . . .	203	Rawlins, C. Alex . . . . .	259
Perry, Scott . . . . .	62, 63	Ream, Paul A. . . . .	267
Peterson, Isabelle . . . . .	45	Reddy, Ramana . . . . .	247
Petri, Brad . . . . .	264	Reed, Rustin J. . . . .	205
Petter, Carlos . . . . .	166	Reed, W. R. . . . .	149
Pickens, Kasie B. . . . .	125	Reeves, Robert . . . . .	280
Pienaar, Alex . . . . .	40	Reid, Doug. . . . .	119
Pierce, B. . . . .	288		

# INDEX: AUTHORS & CHAIRS

- Reisinger, Robert . . . . . 29, 32  
Reiter, Rick . . . . . 9  
Remes, Antti . . . . . 112  
Renne-Malone, Jeannie. . . 18,  
160, 161  
Renner, James. . . . . 86, 98  
Rennkamp, Patrick . . . . . 208  
Resende, Thalita . . . . . 246  
Restrepo Baena,  
Oscar J. . . . . 99, 228  
Restrepo, Julian A. . . . . 273  
Reuter, Marcus A. . . . . 133  
Reyes, Miguel A. . . . . 290  
Rezaee, Mohammad . . . . . 277  
Rezakhah, Mojtaba . . . . . 152  
Rice, Tom . . . . . 195  
Richmond, Michael . . . . . 87  
Rider, James . . . 148, 269, 275  
Ripepi, Nino . . . . . 18, 213  
Ritterbush, Kathleen . . . . . 171  
Robb, Gary . . . . . 83  
Roberts, Lauren . . . . . 6  
Robertson, Georgene . . . . . 48  
Robles, Alex . . . . . 120  
Rocha Gil, María . . . . . 178  
Rockley, Tyler . . . . . 204  
Rodriguez, Damian . . . . . 41  
Roesch, Timo . . . . . 240  
Rogers, Andrew . . . . . 258  
Rogers, Pratt W. . . . . 166, 187  
Roghanchi, Pedram . . . . . 263  
Rojas Mendoza, Lucas . 89, 99  
Rojas, Rosa . . . . . 64, 189  
Romero, Alberto . . . . . 160  
Rosas, Silvia . . . . . 171  
Rose, David . . . . . 104  
Rosenbach, Daniel . . . . . 61  
Rosenthal, Scott . . . . . 284, 285  
Ross, Bradley . . . . . 255, 282  
Ross, Nick . . . . . 156  
Ross, Timothy . . . . . 24  
Rost, Kristen . . . . . 291  
Rostami, Jamal . . . . . 264  
Rostami, Pedram A. . . . . 259  
Rouse, Nathan . . . . . 264  
Rousseau, Frnacis . . . . . 53  
Rozon-Ramilo, Lisa D. . . . 163  
Rucker, Dale . . . . . 109, 110  
Ruff, Todd . . . . . 66, 292  
Russell, Andrew . . . . . 75  
Russell, Michael . . . . . 255  
Saario, Rami . . . . . 185  
Safarzadeh, M. Sadegh . . 111  
Sakamornsnguan, Kridtaya . .  
173  
Saki, Saqib . 28, 220, 221, 274  
Salazar, Abraham . . . . . 22  
Salomon, Jeff . . . . . 64  
Samal, Abani . . . . . 66, 130  
Sample, Zachary T. . . . . 114  
Sanderson, Stuart . . . . . 8  
Saperstein, Lee . . . . . 204  
Sarver, Emily . . . . . 89, 150, 249  
Sattarvand, Javad . . . . . 195  
Scaggs, Meredith L. . . . . 89, 150  
Scargill, Rob . . . . . 5  
Schaefer, Greg . . . . . 5  
Schaeffer, Kevin . . . . . 138  
Schaffer, Michael . . . . . 180  
Schafrik, Steven J. . . . . 83, 147  
Schissler, Andrew P. . . . . 155  
Schlink, Lisa . . . 181, 249, 275  
Schlitt, William . . . . . 45  
Schlueter, Ralf . . . . . 61  
Schmidt, Robin . . . . . 16  
Schnee, Nicholas . . . . . 161  
Schneyer, Joel . . . . . 44  
Scholz, Ben . . . . . 49  
Schramke, Janet . . . . . 36  
Schreiter, Falk . . . . . 182  
Schroeder, Mark . . . . . 192  
Schubert, David . . . . . 42  
Schumacher, P. . . . . 202  
Schunnesson, Hakan . . . . 192  
Scialpi, Martino . . . . . 136  
Scott, Dan . . . . . 278  
Scriven, David . . . . . 280  
Scullin, Matthew . . . . . 238

# INDEX: AUTHORS & CHAIRS

Seibel, Gordon . . . . .	54	Stanley, Fred . . . . .	73
Self, Stefanie . . . . .	87	Stanley, Jaron . . . . .	95, 278
Sellschop, Richard . . . . .	45	Stanley, David . . . . .	232
Sever, Kay M. . . . .	286	Stefanoff, Jim . . . . .	233
Sevilla, Leoncio . . . . .	108	Stepan, Mike . . . . .	127
Shadow, Steve . . . . .	142	Stewart, Craig M. . . . .	261
Shapaka, J. Michael . . . . .	87	Stoll, Katherine . . . . .	92
Sharon, Robert (Bob) . . . . .	288	Stone, Barton G. . . . .	235, 250
Shields, Deborah J. . . . .	159	Stout, Clifford E. . . . .	196
Shiley, Daniel A. . . . .	242	Stull, Luke . . . . .	25
Short, Kevin . . . . .	122	Sturgul, John . . . . .	195
Shriwas, Mahesh . . . . .	85, 220	Su, Daniel . . . . .	25
Shumka, Tom . . . . .	238	Sun, Changshou . . . . .	128
Shumway, Martin R. . . . .	211	Sun, Enji . . . . .	283
Shuri, Frank . . . . .	91	Sun, Hong-Juan . . . . .	168
Shuttleworth, Julie. . . . .	100	Sun, Wei . . . . .	106
Siami Irdemoosa, Elnaz. . . . .	215	Sunkpal, Maurice N. . . . .	263
Silling, Stewart A. . . . .	257	Svedlund, Erik . . . . .	121
Sim, Whuisu . . . . .	113	Swanson, John-Glen . . . . .	269
Skinner, Tim. . . . .	135	Sweetwood, Ryan V. . . . .	31
Sloan, Michael . . . . .	63	Swinderman, Robert T. . . . .	72
Slowik, Dirk . . . . .	126	Syers, Brian . . . . .	191
Smethurst, Andrew . . . . .	184	Tabesh, Mohammad . . . . .	200
Smidt, Erich. . . . .	256	Tadolini, Steve . . . . .	23, 75, 213
Smit, Pieter . . . . .	53	Tahija, Dave . . . . .	103
Smith, Bryan . . . . .	40	Tandoh, Isaac . . . . .	256
Smith, Myron. . . . .	92	Tang, Nathan . . . . .	237
Smith, Terry J. . . . .	217	Tao, Daniel . . . . .	105
Smith, Zack . . . . .	141, 211	Tarigan, Arkadius . . . . .	260
Sobhy, Ahmed. . . . .	105	Tarshizi, Ebrahim 164, 194, 195	
Sobral, Luis . . . . .	109	Tawadrous, Ayman . . . . .	257
Sok, Thien . . . . .	244	Taylor, Danny . . . . .	195
Somasundaran, P. . . . .	131	Taylor, David . . . . .	96
Somers, Jayne . . . . .	19	Taylor, Jonathan . . . . .	258
Sonnenberg, Helga . . . . .	163	Taylor, Patrick . . . . .	247
Sonnier, Rodolphe . . . . .	166	Taylor, Stephen J. . . . .	110
Sotillo, Francisco J. . . . .	98	Tenorio, Victor . . . . .	122, 196
Southwick, Larry . . . . .	103, 248	Thareja, Rahul . . . . .	128, 284
Spiering, Eugene D. . . . .	119	Thomas, Billy . . . . .	75
Spieth, Mathew J. . . . .	162, 235	Thomas, Richard A. . . . .	37, 79
Spitzinger, Jon . . . . .	38	Thompson, James K. . . . .	165
Srivastava, Urvashi . . . . .	247, 249	Thompson, Roger J. . . . .	190
Stagg, Alan K. . . . .	209	Thorpe, Mark . . . . .	30
Stankus, John C. . . . .	82	Tian, Jianjun . . . . .	175

# INDEX: AUTHORS & CHAIRS

- Tien, Jerry . . . . . 120, 221  
Tietjen, Jill . . . . . 29  
Tinney, Darren . . . . . 104, 180  
Tirkkonen, Miika . . . . . 112  
Titus, Liz . . . . . 253  
Tiwari, Prasoon . . . . . 284  
Tomaino, Gary . . . . . 168  
Toole, Brian W. . . . . 144  
Torma-Krajewski, Janet . . 120  
Tovar, Oswaldo . . . . . 188  
Traore, Ismail . . . . . 204  
Treen, Jon . . . . . 50  
Trevits, Mike . . . . . 213, 271  
Tridle, Bob . . . . . 234  
Trippel, Al . . . . . 159  
Tukkaraja, Purushotham . . 84,  
153  
Tuylu, Serkan . . . . . 89  
Upadhyay, Shiv P. . . . . 200  
Urda Kassis, Cynthia . . . . 45  
Usman, Shoaib . . . . . 186  
van der Veen, Peter . . . . . 48  
Van Dyke, Mark . . . . . 25  
van Huyssteen, Johan . . . 176  
Van Ness, John . . . . . 217  
Van Wegen, Simon . . . . . 295  
Vandergrift, Tom . . . . . 24  
Vanlandingham, Jay . . . . . 32  
VanOs, Jacquelyn . . . . . 256  
VAYENAS, Nick . . . . . 125  
Vaz, Patricia . . . . . 109  
Verma, Shubham . . . . . 131  
Videla, Alvaro. . . . . 112  
Villanueva, Juliano . . . . . 105  
Villavisencio, Mario D. . . . 100  
Viriyaatha, Donni . . . . . 289  
Vivas, Raul E. . . . . 55  
Vizcarra, Javier . . . . . 280  
Voltura, Karen . . . . . 88  
Wadhams, Richard . . . . . 9  
Wagner, Rich . . . . . 63, 81  
Wakefield, Todd . . . . . 117  
Walker, Phil . . . . . 45  
Wan, Peter . . . . . 134  
Wang, Bingjian . . . . . 214  
Wang, Eric . . . . . 175,  
Wang, Guoxin . . . . . 96, 106  
Wang, Hongliang . . . . . 56  
Wang, Kai . . . . . 85  
Wang, Liang . . . . . 221  
Wang, Xuming . . . . . 241  
Wang, Yan . . . . . 242  
Warfield, Bill . . . . . 137  
Warkander, Dan E. . . . . 144  
Warren, Sean N. . . . . 129  
Washnock, Robert . . . . . 115  
Watson, Leslie M. . . . . 231  
Weber, Colin . . . . . 287  
Wedding, William C. . . . . 148  
Weeks, James L. . . . . 206  
Weinig, Walter . . . . . 29  
Weiss, Chester J. . . . . 147  
Wempen, Jessica M. . . 24, 129  
Wen, Hu . . . . . 21, 85  
Westendorf, Mike . . . 104, 180  
Westman, Dr. Erik . . . . . 75, 283  
Weyer, Jürgen . . . . . 26, 260  
Whalen, Devon . . . . . 177  
White, Trey . . . . . 191  
Whitney, Joshua A. . . . . 65  
Wientjes, J.D. . . . . 151  
Wiley, Livia . . . . . 111  
Wilkinson, Pamela K. . . . . 46  
Williams, Mike . . . . . 123  
Williamson, Mark A. . . . . 156  
Williamson, Patrick T. . . . . 172  
Willmer, Dana R. . . . . 286  
Wilson, Anna B. . . . . 43  
Witucki, Richard . . . . . 123  
Wood, Tim . . . . . 6  
Wu, Yuanli . . . . . 208  
Wyatt, Chris . . . . . 138, 210  
Wyberneit, Olaf . . . . . 196  
Xing, Meiyu . . . . . 186  
Xiong, Ryan . . . . . 106  
Xiong, Yu . . . . . 245  
Yang, Fenghua . . . . . 120  
Yang, Xiacong . . . . . 167

# INDEX: AUTHORS & CHAIRS

Yang, Yihong . . . . .	244	Zhang, Jian Ray . . . . .	201
Yates, Richard K. . . . .	121	Zhang, Jie . . . . .	167
Yee, Steven . . . . .	143, 150	Zhang, Jinhong . . . . .	106
Yin, Xihui . . . . .	246	Zhang, Joy . . . . .	237
Yonkey, Jeff . . . . .	147	Zhang, Kuangyuan . . . . .	189
Yoon, Roe-Hoan . . . . .	107, 113, 246	Zhang, Li . . . . .	167
Yorio, Patrick L. . . . .	286	Zhang, M. . . . .	247
York-Feirn, William . . . . .	253	Zhang, Wei . . . . .	106
Young, Courtney A. . . . .	249	Zhang, Wen Z . . . . .	80
Young, Jacob . . . . .	154	Zhang, Yanni . . . . .	85
Young, Michael . . . . .	139, 176	Zhang, Yijun . . . . .	143
Zablocki, Craig . . . . .	212	Zhang, Yumo . . . . .	21
Zabrusky, Kelsey . . . . .	250	Zhao, Ming . . . . .	240
Zaffron, Steve . . . . .	115	Zheng, Yi . . . . .	275
Zamiran, Siavash. . . . .	282	Zhou, Guobiao. . . . .	168
Zaske, Marvin . . . . .	281	Zhou, Lihong . . . . .	275
Zdunczyk, Justin . . . . .	164	Zingsheim, Moritz . . . . .	68
Zeni, Nathan . . . . .	207	Zuback, Rachel . . . . .	93
Zhai, Xiaowei . . . . .	85, 219		

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*The following sessions feature health and safety related papers and presentations.*

## Monday, February 16, 2015

### Coal and Energy

- The Best of Ground Control
- Ventilation Best Practices

### Mining and Exploration

- Underground Mining Projects and Innovation I
- Utilizing Simulators for Mine Equipment Training
- Professional Responsibility and Safety
- Stope Design Technologies

## Tuesday, February 17, 2015

### Coal and Energy

- Mining Research and Development
- Underground Mining Processes and Practices
- Ventilation Best Practices II
- Dust Control I

### Industrial Minerals and Aggregates

- Health and Safety

### Environmental

- Responsible Mining Environmental and Social Risks I

### Bulk Material Handling

- Improvements in Conveyor Maintenance and Safety

### Mining and Exploration

- Building a Safety Culture
- Developments and Implementation in Rock Mechanics and Ground Control

### Research

- NORA Safety and Health Research for Small Mines

## Wednesday, February 18, 2015

### Coal and Energy

- Ventilation Innovations I
- Underground Mining Innovations
- Innovations and Improvements
- Dust Control II
- Ventilation Innovations II
- Mine Emergency Response
- Breathing Air Supplies

### Environmental

- Water Treatment II: Arsenic, Selenium and Other Contaminants
- Responsible Mining Environmental and Social Risks II

### Mining and Exploration

- Underground Mine Ventilations
- Management: MSHA
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