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ONSITE PROGRAM

This Onsite Program has several references to help you quickly find what you need.

QUICK GUIDE

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GENERAL INFORMATION

CONFERENCE LOCATION

All technical sessions, division luncheons and short courses will be conducted at:

Colorado Convention Center
700 14th Street, Denver, CO 80202
(303) 228-8000
www.denverconvention.com

AUTHORS' COFFEE

Colorado Convention Center **201 – 207**

All SME presenting authors and chairs should attend the Authors' Coffee on the day of their presentation from 7:30 am – 8:30 am.

MEETING PREPRINTS

Pick up at SME Bookstore
Colorado Convention Center **Lobby A**

Each full, one-day and student registrant will receive a flash drive of preprints from the 2017 SME Annual Conference & Expo and CMA 119th National Western Mining Conference. Additional flash drives are available for purchase in the SME Bookstore. (Offer excludes discounted and short course and exhibits-only registrations.) If you do not pickup your preprint USB during the meeting, we can mail it upon request until May 1,2017 but you will be invoiced for postage/shipping.

Registrants of the Intergenerational Symposium on Mining with Backfill can also pickup their electronic proceedings at the SME Bookstore.

COAT CHECK

Colorado Convention Center **Lobby A**

Sunday, February 19	3:00 pm – 7:00 pm
Monday, February 20	7:00 am – 6:00 pm
Tuesday, February 21	7:00 am – 6:00 pm
Wednesday, February 22	7:00 am – 2:00 pm

SPEAKER READY ROOM

Colorado Convention Center **201 – 207**

Audio visual representatives will be available to assist SME authors during the following hours:

Monday, February 20	7:30 am – 5:00 pm
Tuesday, February 21	7:30 am – 5:00 pm
Wednesday, February 22	7:30 am – 5:00 pm

SME TECHNICAL SESSION LOCATIONS

Colorado Convention Center

All technical sessions will be conducted at the Colorado Convention Center.

GENERAL **INFORMATION**

SME RESOURCE CENTER

Exhibit Hall **Booth 1811**

The SME Resource Center will be located in the exhibit hall at the Colorado Convention Center. The Center will feature *Mining Engineering* magazines, SME Foundation, Minerals Education Coalition and SME Division information. Come gather here during the exhibit hours.

REGISTRATION, MEMBERSHIP, TICKET BOOTH AND BOOKSTORE HOURS

Colorado Convention Center **Lobby A**

Attendees must register to purchase tickets for social functions and/or field trips. Registrants may purchase multiple tickets.

The SME Bookstore will feature mining industry books and publications. You can also pick up your copy of the pre-print flash drive of the 2017 SME Annual Conference & Expo and CMA 119th National Western Mining Conference by redeeming the ticket enclosed in your registration packet on-site.

The SME Bookstore, Registration, Membership and Ticket Booth hours are:

Saturday, February 18	7:00 am – 5:00 pm
Sunday, February 19	7:00 am – 6:00 pm
Monday, February 20	7:00 am – 5:30 pm
Tuesday, February 21	7:00 am – 5:30 pm
Wednesday, February 22	7:00 am – 2:00 pm

EXHIBIT HOURS

Exhibit Hall **A – C**

Exhibitor products and services will be showcased at the 2017 SME Annual Conference & Expo and CMA 119th National Western Mining Conference at the Colorado Convention Center. Badges are required for admittance. All food and beverage functions held in the exhibit hall will be located on the exhibit floor.

Sunday, February 19	4:00 pm – 6:00 pm
Monday, February 20	11:00 am – 5:30 pm
Tuesday, February 21	11:00 am – 5:30 pm
Wednesday, February 22	8:00 am – Noon

SME PRESS ROOM & MEDIA CENTER

Colorado Convention Center **103**

The SME Press Room & Media Center will be available for members of the press during core hours Feb. 20-22. Conference exhibitors will display samples of their new products using media kits, flash drives, brochures and samples. High level executives and exhibitor representatives will be interviewed at designated times, with the interviews transmitted live via streaming video on the SME Facebook platform. Exhibitors will have the opportunity to announce their new products, also via live streaming.

GENERAL INFORMATION

(Continued)

REGISTRATION POLICY

All attendees and authors at the official 2017 SME Annual Conference & Expo and CMA 119th National Western Mining Conference are required to register. Nonmember authors may register at the member rate. The one-day rate is available only for the day you want to attend (Sunday, Monday, Tuesday or Wednesday). The appropriate badge is required for admittance to the technical sessions and exhibits and will be checked at the entrance of all activities. Attendees interested in touring only the exhibit can purchase a one-day pass. Exhibit-only registrations are NOT permitted to attend the technical sessions.

LEGION OF HONOR REGISTRATION POLICY

Legion of Honor Members are entitled to receive reduced registration fees for the 2017 SME Annual Conference & Expo and CMA 119th National Western Mining Conference. Attendees requesting this category of registration must meet eligibility requirements and must be on record at SME as a Legion of Honor Member. A Legion of Honor Member must have acquired 50 years of uninterrupted membership. SME Members are automatically moved to this membership class.

SENIOR MEMBER REGISTRATION POLICY

Retired Senior Members are entitled to receive reduced registration fees for the 2017 SME Annual Conference & Expo and CMA 119th National Western Mining Conference. Attendees requesting this category of registration must meet eligibility requirements and must be on record at SME as a Senior Member. A Senior Member is a retired member who has reached 70 years of age with 30 continuous years of membership with SME. Individuals must contact the SME Membership Department and request this category of membership (based on qualifications). Questions regarding Senior Member status should be directed to the SME Membership Manager at 303-948-4200.

STUDENT REGISTRATION POLICY

Student registrants for the 2017 SME Annual Conference & Expo and CMA 119th National Western Mining Conference must meet eligibility requirements. SME requires that an individual must be attending a college, university or higher education institution on a full-time basis to qualify for student registration rates. SME cannot process student registrations without evidence that you are a full-time student. Students enrolled in 12 or more semester credit hours are considered full-time. When sending your registration, please provide registration confirmation from your educational institution. Acceptable confirmation includes: transcript, most recent report card or official school registration documents. Student registration forms without this information will not be processed.

CANCELLATION/SUBSTITUTION POLICY

If circumstances require you to cancel your SME registration, you must do so in writing. Written notice must be sent to **SME Meeting Registration, c/o Experient, PO Box 4088, Frederick, MD 21705**. Cancellations received by January 23, 2017 will receive a full refund, less a $100 processing fee. There are no refunds for no-shows and cancellations postmarked after January 23, 2017. Registrants are responsible for cancellation of their own hotel accommodations. Substitutions will be accepted in writing at no charge until January 23, 2017. After January 23, 2017 a $25 fee will be charged for substitutions.

NO REFUNDS

For registration, short course, social function, tour and field trip tickets no refunds issued after the **January 23, 2017 DEADLINE**.

GENERAL INFORMATION

(Continued)

OFFICIAL CONFERENCE HOTELS

CROWNE PLAZA
1450 Glenarm Place, Denver, CO 80202
Phone: 303-573-1450

EMBASSY SUITES DOWNTOWN
1420 Stout Street, Denver, CO 80202
Phone: 303-592-1000

GRAND HYATT
1750 Welton Street, Denver, CO 80202
Phone: 303-295-1234

HAMPTON INN & SUITES
550 15th Street, Denver, CO 80202
Phone: 303-864-8000

HILTON GARDEN INN
1400 Welton Street, Denver, CO 80202
Phone: 303-603-8000

HOMEWOOD SUITES
550 15th Street, Denver, CO 80202
Phone: 303-534-7800

HYATT HOUSE/HYATT PLACE DOWNTOWN
440 14th Street, Denver, CO 80202
Phone: 303-893-3100

HYATT REGENCY AT COLORADO CONVENTION CENTER
650 15th Street, Denver, CO 80202
Phone: 303-436-1234

MARRIOTT CITY CENTER
1701 California Street, Denver, CO 80202
Phone: 303-297-1300

SHERATON DENVER
1550 Court Place, Denver, CO 80202
Phone: 303-893-3333

WESTIN DENVER DOWNTOWN
1672 Lawrence Street, Denver, CO 80202
Phone: 303-572-9100

2017 SME/CMA KEYNOTE SESSION

Monday, February 20, 2017

8:30 am

Colorado Convention Center – Four Seasons Ballroom 2-4

Sponsored by:

BARRICK

WHEN ARE COMMODITY PRICES GOING TO REBOUND?

The Grand Recession resulted in a massive contraction of the global economy. Commodity prices suffered as manufacturing stalled and China's economic growth slowed. Today, the minerals industry still suffers from poor prices, a lack of investor interest and a general economic malaise. There are many causes for this downturn but our futures depend on understanding and predicting the catalysts of change that will improve commodity prices.

This presentation will discuss how the world has changed in the past ten years, its impact on commodity prices and the ramifications to the minerals industry. If ideas are food for thought, this presentation will be a smorgasbord.

Douglas B. Silver is a portfolio manager for Orion Mine Finance, a private-equity fund focused on providing funding to advanced-stage base and precious metal projects. Prior to joining Orion, Douglas served as CEO and Chairman of International Royalty Corporation, a global mineral royalty company which he founded in 2003 and sold in 2011. From 1987 to 2004, his private company, Balfour Holdings, Inc., was involved in an array of global assignments ranging from business development, behavioral profiling of competing bidders, capital raising, transaction negotiations, appraisals, investor relations and special Board-level requests. In his spare time, Douglas chairs the Lowell Institute of Mineral Resources and sits on the College of Science Advisory Board at the University of Arizona.

Over the years, Douglas has been very active in SME. He wrote the Economic and Finance column for Mining Engineering from 1996 to 2011, has presented 17 times at SME conferences, and chaired eight sessions (including two keynote sessions). In his 2008 SME Keynote address, he predicted the Grand Recession. He is the recipient of the Distinguished Service Award, SME President's award, the Henry Krumb Lecturer award and William Lawrence Saunders Gold Medal.

CALENDAR OF EVENTS

FRIDAY, FEBRUARY 17

Exhibitor Set-up (10x20 booths and larger, by appointment only)
11:00 am – 5:00 pm | Hall A-C | CCC | General

SATURDAY, FEBRUARY 18

Attendee Registration			
7:00 am – 5:00 pm	Lobby A	CCC	General
YL Field Trip – Climax Molybdenum Mine			
7:00 am – 5:00 pm			
ESS Symposium: Breakfast			
7:00 am – 8:00 am	702-704	CCC	ESS
Short Courses Coffee Break			
7:15 am – 9:00 am	109-113	CCC	Short Courses
ESS Symposium: Session			
8:00 am – 5:00 pm	709	CCC	ESS
Exhibitor Registration			
8:00 am – 5:00 pm	Lobby A	CCC	General
Exhibitor Set-up			
8:00 am – 5:00 pm	Hall A-C	CCC	General
SME Bookstore			
8:00 am – 5:00 pm	Lobby A	CCC	General
Leadership Orientation			
8:00 am – Noon	Mineral Hall F-G	Hyatt	Board & Committee
SME Foundation Executive Committee Meeting			
8:00 am – 10:00 am	Granite A	Hyatt	Board & Committee
WAAIME Bylaws Meeting			
8:30 am – 3:00 pm	Mineral Hall C	Hyatt	Board & Committee
Short Course: Gold Processing Practices: Fundamentals, Plant Operations and Optimization			
9:00 am – 5:00 pm	102	CCC	Short Courses
Short Course: Mine-to-Mill Process Optimization			
9:00 am – 5:00 pm	104	CCC	Short Courses
Short Course: Mine Waste Management, Tailings and Waste Rock: Technologies and Techniques			
9:00 am – 5:00 pm	110-112	CCC	Short Courses
Short Course: Optimization with Risk Management in Strategic Mining Planning			
9:00 am – 5:00 pm	107	CCC	Short Courses
Audit Committee Meeting			
9:00 am – 11:00 am	Granite B	Hyatt	Board & Committee
ESS Symposium: Break			
10:15 am – 10:30 am	705-707	CCC	ESS
Short Courses Coffee Break			
10:15 am – 10:30 am	109-113	CCC	Short Courses

ABET Training Lunch
Noon – 1:00 pm | Mineral Hall B-C | Hyatt | Board & Committee

ESS Symposium: Lunch
Noon – 1:00 pm | 702-704 | CCC | ESS

Short Courses Lunch
Noon – 1:00 pm | 109-113 | CCC | Short Courses

ABET Training Meeting
1:00 pm – 5:00 pm | Mineral Hall F-G | Hyatt | Board & Committee

Pre-test/Mineral Processing Exam Meeting
1:00 pm – 5:00 pm | 204 | CCC | Board & Committee

Education and Prof. Development Strategic Committee
1:00 pm – 4:00 pm | Mineral Hall A | Hyatt | Board & Committee

Finance Strategic Committee Meeting
1:00 pm – 4:00 pm | Granite B | Hyatt | Board & Committee

Outreach Strategic Committee Meeting
1:00 pm – 4:00 pm | Mineral Hall D | Hyatt | Board & Committee

Products & Services Strategic Committee Meeting
1:00 pm – 4:00 pm | Granite A | Hyatt | Board & Committee

Structure & Goverance Strategic Committee Meeting
1:00 pm – 4:00 pm | Mineral Hall E | Hyatt | Board & Committee

Tailings Impoundment Committee Meeting
2:00 pm – 4:00 pm | 206 | CCC | Board & Committee

Short Courses Break
2:30 pm – 3:00 pm | 109-113 | CCC | Short Courses

ESS Symposium: Break
2:30 pm – 2:45 pm | 705-707 | CCC | ESS

Strategic Committees Joint Meeting
4:00 pm – 5:00 pm | Mineral Hall A-C | Hyatt | Board & Committee

ESS Symposium: Poster Sessions
5:00 pm – 7:00 pm | 705-707 | CCC | ESS

ESS Symposium: Reception
5:00 pm – 7:00 pm | 705-707 | CCC | ESS

SME Board of Directors Meeting (closed session)
5:00 pm – 6:30 pm | Granite A | Hyatt | Board & Committee

SUNDAY, FEBRUARY 19

Attendee Registration
7:00 am – 6:00 pm | Lobby A | CCC | General

SME Bookstore
7:00 am – 6:00 pm | Lobby A | CCC | General

Exhibitor Registration
7:00 am – 4:00 pm | Lobby A | CCC | General

SME/NSSGA Student Design Competition (Final Presentations)
7:00 am – 2:00 pm | Capitol 5 | Hyatt | Board & Committee

Foundation Corporate Giving Committee
7:00 am – 9:00 am | Mineral Hall D | Hyatt | Board & Committee

CALENDAR OF **EVENTS**

(Continued)

Foundation Individual Fundraising Committee	7:00 am – 9:00 am	Mineral Hall E	Hyatt	Board & Committee
ESS Symposium: Breakfast	7:00 am – 8:00 am	702-704	CCC	ESS
Short Courses Coffee Break	7:15 am – 9:00 am	109-113	CCC	Short Courses
ESS Symposium: Session	8:00 am – 5:30 pm	709	CCC	ESS
Professional Engineers Exam Committee Workshop and Business Meeting	8:00 am – 4:30 pm	Mineral Hall B-C	Hyatt	Board & Committee
Exhibitor Set-up	8:00 am – 2:00 pm	Hall A-C	CCC	General
MPD Division Executive Committee Meeting	8:00 am – Noon	Centennial A	Hyatt	Board & Committee
WAAIME: Finance & Executive Committee Meeting	8:00 am – 11:30 am	Granite A	Hyatt	Board & Committee
Mineral School Department Heads Meeting	8:00 am – 11:00 am	Capitol 1-2	Hyatt	Board & Committee
Student Engagement Breakfast	8:30 am – 11:00 am	Capitol 4	Hyatt	Board & Committee
Short Course: Gold Processing Practices: Fundamentals, Plant Operations and Optimization	9:00 am – 5:00 pm	102	CCC	Short Courses
Short Course: Mine Backfill Technology	9:00 am – 5:00 pm	210-212	CCC	Short Courses
Short Course: Mine-to-Mill Process Optimization	9:00 am – 5:00 pm	104	CCC	Short Courses
Short Course: Mine Waste Management, Tailings and Waste Rock: Technologies and Techniques	9:00 am – 5:00 pm	110-112	CCC	Short Courses
Short Course: Optimization with Risk Management in Strategic Mining Planning	9:00 am – 5:00 pm	107	CCC	Short Courses
Coal & Energy Division Executive Committee Meeting	9:00 am – Noon	Capitol 3	Hyatt	Board & Committee
Environmental Executive Committee	9:00 am – Noon	Mineral Hall A	Hyatt	Board & Committee
Health & Safety Division Executive Meeting	9:00 am – Noon	Granite B	Hyatt	Board & Committee
IM&AD Division Executive Committee	9:00 am – Noon	Capitol 6	Hyatt	Board & Committee

M&E Division Executive Committee Meeting
9:00 am – Noon | Capitol 7 | Hyatt | Board & Committee

ESS Symposium: Break
10:00 am – 10:15 am | 705-707 | CCC | ESS

Short Courses Coffee Break
10:15 am – 10:30 am | 109-113 | CCC | Short Courses

SME Board of Directors Meeting
11:30 am – 4:00 pm | Mineral Hall F-G | Hyatt | Board & Committee

ESS Symposium: Lunch
11:45 am – 12:45 pm | 702-704 | CCC | ESS

Short Courses Lunch
12:00 pm – 1:00 pm | 109-113 | CCC | Short Courses

ADTI Subcommittee Meeting
1:00 pm – 4:00 pm | Mineral Hall A | Hyatt | Board & Committee

Health & Safety Division Planning Committee Meeting
1:00 pm – 4:00 pm | Granite B | Hyatt | Board & Committee

IM&AD Division Program Committee Meeting
1:00 pm – 4:00 pm | Capitol 6 | Hyatt | Board & Committee

Caterpillar Student Forum and Reception
1:00 pm – 3:00 pm | 605-607 | CCC | Board & Committee

Coal & Energy Divisions Unit Committee Meeting
2:00 pm – 3:00 pm | Capitol 3 | Hyatt | Board & Committee

MPD Division Unit Committee Meeting
2:00 pm – 3:00 pm | Centennial A | Hyatt | Board & Committee

Short Courses Break
2:30 pm – 3:00 pm | 109-113 | CCC | Short Courses

2017 Educators' Forum
3:00 pm – 5:00 pm | 601-603 | CCC | Board & Committee

Coal & Energy Division Nominating Committee Meeting
3:00 pm – 5:00 pm | Capitol 3 | Hyatt | Board & Committee

Mentor Meeting Place
3:00 pm – 5:00 pm | 710-712 | CCC | Board & Committee

Young Leaders Committee Meeting
3:00 pm – 5:00 pm | Capitol 4 | Hyatt | Board & Committee

ESS Symposium: Break
3:15 pm – 3:30 pm | 705-707 | CCC | ESS

Grand Opening Reception in Exhibit Hall
4:00 pm – 6:00 pm | Hall A-C | CCC | Social

Annual Meeting of the Members
4:00 pm – 5:00 pm | Mineral Hall F-G | Hyatt | Board & Committee

Mining with Backfill Symposium: Welcoming Reception
5:30 pm – 7:00 pm | Capitol 5 | Hyatt | Minefill

SME Foundation Gala Dinner and Silent Auction
6:00 pm – 11:00 pm | Centennial D-H | Hyatt | Social

CALENDAR OF EVENTS

(Continued)

MONDAY, FEBRUARY 20

2nd Annual SME Heath & Safety 5K Meeting Place			
6:30 am – 8:30 am	101	CCC	Social
Attendee Registration			
7:00 am – 5:30 pm	Lobby A	CCC	General
Exhibitor Registration			
7:00 am – 5:30 pm	Lobby A	CCC	General
SME Bookstore			
7:00 am – 5:30 pm	Lobby A	CCC	General
MPD Division Nominating Committee Meeting			
7:00 am – 9:00 am	Marble	Hyatt	Board & Committee
OTC Program Committee Meeting			
7:00 am – 9:00 am	Sandstone	Hyatt	Board & Committee
WFEO Task Force			
7:00 am – 8:30 am	204	CCC	Board & Committee
Speaker Ready Room			
7:30 am – 5:00 pm	201-207	CCC	General
Author's Coffee			
7:30 am – 8:30 am	201-207	CCC	General
WAAIME Scholarship Meeting			
8:00 am – Noon	Mineral Hall A	Hyatt	Board & Committee
Environmental Division Business Meeting			
8:00 am – 9:00 am	206	CCC	Board & Committee
IM&AD Division Technical Committee Meeting			
8:00 am – 9:00 am	208	CCC	Board & Committee
Keynote Session			
8:30 am – 11:00 am	Four Seasons Ballroom 2-4	CCC	General
Mining with Backfill Symposium: Technical Sessions			
9:00 am – 5:00 pm	603	CCC	Minefill
Mining with Backfill Symposium: AM Coffee Break			
10:00 am – 10:30 am	605	CCC	Minefill
Exhibit Hall			
11:00 am – 5:30 pm	Hall A-C	CCC	General
Annual Spouse/Guest Brunch			
11:00 am – 1:00 pm	Peaks Lounge (27th Floor)	Hyatt	Social
Young Leaders Mentoring Luncheon (by ticket only)			
11:00 am – 1:00 pm	111	CCC	Board & Committee
Section Leaders Lunch			
11:30 am – 1:00 pm	607	CCC	Board & Committee
Bulk Material Handling Committee Meeting			
11:30 am – 1:00 pm	604	CCC	Board & Committee

Conference Luncheon in Exhibit Hall
11:30 am – 1:00 pm | Hall A-C | CCC | General

Foundation Corporate Roundtable Luncheon (by invitation only)
Noon – 1:30 pm | 109 | CCC | Social

Accreditation and Curricular Issues Subcommittee Meeting
1:00 pm – 3:00 pm | 606 | CCC | Board & Committee

Government & Public Affairs Committee Meeting
1:00 pm – 3:00 pm | 204 | CCC | Board & Committee

WAAIME 100th Anniversary Reception Committee Meeting
1:00 pm – 3:00 pm | Mineral Hall A | Hyatt | Board & Committee

CMA: Mining in Colorado Session/Meeting of the Members
1:30 pm – 5:00 pm | 710-712 | CCC | CMA

Dreyer Lecture
1:30 pm – 3:00 pm | 113 | CCC | General

MPD Plenary Session
2:00 pm – 4:30 pm | 705-709 | CCC | General

OneMine Board Meeting
2:00 pm – 4:00 pm | Mineral Hall D | Hyatt | Board & Committee

2018 CMA 120th National Western Mining Conference Exhibit Space Sales
3:00 pm – 5:00 pm | Hall A-C | CCC | General

2018 SME Annual Conference & Expo Exhibit Space Sales
3:00 pm – 5:00 pm | Hall A-C | CCC | General

ABET Visitor Selection Meeting (closed)
3:00 pm – 5:00 pm | 604 | CCC | Board & Committee

Mining with Backfill Symposium: PM Coffee Break
3:00 pm – 3:30 pm | 605 | CCC | Minefill

IM&AD Division Nominating Committee Meeting
4:00 pm – 6:00 pm | Mineral Hall B-C | Hyatt | Board & Committee

Competency Task Force Meeting
4:00 pm – 5:30 pm | Sandstone | Hyatt | Board & Committee

Dreyer Award Committee Meeting
4:00 pm – 5:30 pm | 101 | CCC | Board & Committee

New Member Orientation & Reception
5:00 pm – 6:30 pm | 109-113 | CCC | Social

Remember Wilberg Documentary Film Screening
5:00 pm – 6:30 pm | 705-709 | CCC | General

Rising Professionals Social (ticketed)
7:00 pm – 9:00 pm | Agate | Hyatt | Social

TUESDAY, FEBRUARY 21

Attendee Registration
7:00 am – 5:30 pm | Lobby A | CCC | General

SME Bookstore
7:00 am – 5:30 pm | Lobby A | CCC | General

Foundation Board of Trustees Meeting
7:00 am – 9:00 am | Capitol 4 | Hyatt | Board & Committee

CALENDAR OF **EVENTS**

(Continued)

Sustainable Development Committee Meeting			
7:00 am – 9:00 am	Mineral Hall B-C	Hyatt	Board & Committee
Women of SME, WAAIME, and WIM Breakfast (ticketed)			
7:00 am – 9:00 am	Centennial A-B	Hyatt	Social
Minerals & Metal Processing Editorial Board Meeting			
7:00 am – 8:30 am	Granite A	Hyatt	Board & Committee
Speaker Ready Room			
7:30 am – 5:00 pm	201-207	CCC	General
Author's Coffee			
7:30 am – 8:30 am	201-207	CCC	General
Health and Safety Division Breakfast (ticketed)			
7:30 am – 8:30 am	607	CCC	Social
Research Subcommittee Meeting			
8:00 am – 9:00 am	206	CCC	Board & Committee
Mineral Processing & Extractive Metallurgy Breakfast (invitation only)			
8:30 am – 9:30 am	Mineral Hall D	Hyatt	Social
CMA: Sessions			
9:00 am – 5:00 pm	710-712	CCC	CMA
Mining with Backfill Symposium: Technical Sessions			
9:00 am – 5:00 pm	603	CCC	Minefill
Technical Papers Peer Review Editorial Board			
9:00 am – 10:00 am	Capitol 1	Hyatt	Board & Committee
2018 CMA 120th National Western Mining Conference Exhibit Space Sales			
10:00 am – 5:00 pm	Hall A-C	CCC	General
2018 SME Annual Conference & Expo Exhibit Space Sales			
10:00 am – 5:00 pm	Hall A-C	CCC	General
Student Member Affairs Subcommittee Meeting			
10:00 am – Noon	606	CCC	Board & Committee
***Mining Engineering* Magazine Editorial Board Meeting**			
10:00 am – 11:00 am	604	CCC	Board & Committee
Mining with Backfill Symposium: AM Coffee Break			
10:00 am – 10:30 am	605	CCC	Minefill
Exhibit Hall			
11:00 am – 5:30 pm	Hall A-C	CCC	General
Coal & Energy Division Luncheon (ticketed)			
Noon– 1:45 pm	Four Seasons Ballroom 2-3	CCC	Social
IM&AD Division Lunch (ticketed)			
Noon – 1:45 pm	Four Seasons Ballroom 4	CCC	Social
Environmental Division Lunch (ticketed)			
Noon – 1:30 pm	Four Seasons Ballroom 1	CCC	Social

Mining with Backfill Symposium: Hosted Luncheon			
Noon – 1:00 pm	605	CCC	Minefill
EduMine/CIM/SME Online Learning Campus Committee Meeting			
1:30 pm – 3:00 pm	602	CCC	Board & Committee
Coal & Energy Division Business Meeting			
1:45 pm – 2:00 pm	Four Seasons Ballroom 2-3	CCC	Board & Committee
IM&AD Division Business Meeting			
1:45 pm – 2:00 pm	Four Seasons Ballroom 4	CCC	Board & Committee
Council of Education Meeting			
3:00 pm – 5:00 pm	206	CCC	Board & Committee
Information Publishing Committee Meeting			
3:00 pm – 5:00 pm	Mineral Hall A	Hyatt	Board & Committee
Mining with Backfill Symposium: PM Coffee Break			
3:00 pm – 3:30 pm	605	CCC	Minefill
Afternoon Social in Exhibit Hall			
3:30 pm – 5:30 pm	Hall A-C	CCC	Social
Bulk Materials Handling Poster Session			
4:00 pm – 6:30 pm	109-113	CCC	Social
Move Mining Competition			
4:00 pm – 5:45 pm	203	CCC	General
Coal & Energy and M&E Underground Ventilation Committee Meeting			
4:00 pm – 5:00 pm	607	CCC	Board & Committee
WAAIME 100th Anniversary Reception & Alumni Reception			
5:30 pm – 7:30 pm	Centennial D-H	Hyatt	Social
International Attendees Reception (invitation only)			
5:30 pm – 7:00 pm	Capitol 1-3	Hyatt	Social
IM&AD Division Executive Committee Mentoring Meeting			
5:30 pm – 6:30 pm	208	CCC	Board & Committee
CMA Environmental Stewardship Awards Reception & Banquet			
6:00 pm – 9:30 pm	Centennial A-C	Hyatt	CMA
Scotch Nightcap MPD Division Scholarship Fundraiser (ticketed)			
8:00 pm – 11:00 pm	Capitol 1-4	Hyatt	Social

WEDNESDAY, FEBRUARY 22

Attendee Registration			
7:00 am – 2:00 pm	Lobby A	CCC	General
SME Bookstore			
7:00 am – 2:00 pm	Lobby A	CCC	General
SME Valuation Standards Committee Meeting			
7:00 am – 9:00 am	Granite A-C	Hyatt	Board & Committee
Speaker Ready Room			
7:30 am – 5:00 pm	201-207	CCC	General

CALENDAR OF EVENTS

(Continued)

2018 SME Annual Conference Program Committee Meeting			
7:30 am – 9:00 am	201	CCC	Board & Committee
SME/AIME Past Presidents Breakfast (invitation only)			
7:30 am – 9:00 am	Capitol 1-3	Hyatt	Board & Committee
Author's Coffee			
7:30 am – 8:30 am	201-207	CCC	General
Exhibit Hall			
8:00 am – Noon	Hall A-C	CCC	General
2018 CMA 120th National Western Mining Conference Exhibit Space Sales			
8:00 am – 11:00 am	Hall A-C	CCC	General
2018 SME Annual Conference & Expo Exhibit Space Sales			
8:00 am – 11:00 am	Hall A-C	CCC	General
Continental Breakfast in Exhibit Hall			
8:00 am – 9:30 am	Hall A-C	CCC	Social
Education Sustainability Committee			
8:30 am – Noon	208	CCC	Board & Committee
Resources & Reserves Committee Meeting			
8:30 am – 10:00 am	204	CCC	Board & Committee
Mining with Backfill Symposium: Technical Sessions			
9:00 am – 5:00 pm	603	CCC	Minefill
CMA: Sessions			
9:00 am – Noon	710-712	CCC	CMA
2019 SME Annual Conference Program Committee Meeting			
9:00 am – 10:00 am	201	CCC	Board & Committee
Distinguished Member Award Nominating Committee			
10:00 am – 11:00 am	101	CCC	Board & Committee
SME Registered Member Admissions Committee/SME Registered Member Ethics Committee Meeting			
11:00 am – 1:00 pm	604	CCC	Board & Committee
Exhibitor Move-Out			
Noon – 8:00 pm	Hall A-C	CCC	General
CMA Closing Awards Luncheon			
Noon – 2:00 pm	Four Seasons Ballroom 4	CCC	CMA
M&E Division Lunch (ticketed)			
Noon – 2:00 pm	Four Seasons Ballroom 2-3	CCC	General
MPD Division Lunch/Student Poster Session (ticketed)			
Noon – 1:45 pm	Four Seasons Ballroom 1	CCC	General

Mining with Backfill Symposium: Hosted Luncheon			
Noon – 1:00 pm	605	CCC	Minefill
Minerals Education Coalition Committee Meeting			
1:00 pm – 4:00 pm	109	CCC	Board & Committee
Jackling Lecture (during M&E Division Lunch)			
1:30 pm – 2:00 pm	Four Seasons Ballroom 2-3	CCC	General
MPD Division Business Meeting			
1:45 pm – 2:00 pm	Four Seasons Ballroom 1	CCC	Board & Committee
International Committee Meeting			
2:00 pm – 4:00 pm	606	CCC	Board & Committee
M&E Division Business Meeting			
2:00 pm – 2:30 pm	Four Seasons Ballroom 2-3	CCC	Board & Committee
M&E Division Unit Committee Meeting			
2:30 pm – 3:30 pm	Four Seasons Ballroom 2-3	CCC	Board & Committee
Student Mentor Meeting			
3:00 pm – 6:00 pm	Four Seasons Ballroom 1	CCC	Board & Committee
Environmental Division Nominating & Planning Committee			
3:00 pm – 5:00 pm	204	CCC	Board & Committee
SME Strategic Nominating Committee Meeting (closed)			
3:00 pm – 5:00 pm	208	CCC	Board & Committee
MPD Division Executive Committee Meeting			
3:00 pm – 4:00 pm	206	CCC	Board & Committee
SME/AIME Awards Banquet (ticketed)			
6:00 pm – 10:00 pm	Centennial D-E	Hyatt	Social
SME Dinner VIP Reception			
6:00 pm – 7:00 pm	Centennial F-G	Hyatt	Social
President's Reception (invitation only)			
9:30 pm – Midnight	Centennial F-G	Hyatt	Social

THURSDAY, FEBRUARY 23

Exhibitor Move-Out			
7:00 am – Noon	Hall A-C	CCC	General
SME Board of Directors Meeting			
8:00 am – Noon	Mineral Hall F-G	Hyatt	General

SPECIAL **ACTIVITIES**

HEALTH & SAFETY 5K FUN RUN

Monday, February 20

6:30 am

Meet in room 101 at the Colorado Convention Center beginning at 6:30 am.

Tickets: $35

SPOUSE/GUEST MEET & GREET BRUNCH

Monday, February 20

11:00 am – 1:00 pm

Hyatt Regency Denver – Peaks Lounge, 27th floor

If you are registered as a Spouse/Guest, please attend this event planned specifically for you. Meet guests of honor Liz Arnold, spouse of 2016 SME president Steve Gardner, and Margi Mansanti, spouse of 2017 SME president John Mansanti as well as the spouses and guests of meeting attendees while enjoying a light brunch. You'll reconnect with old friends and meet new ones.

LOCAL SECTION LEADERS MEETING & LUNCHEON

Monday, February 20

11:30 am – 1:30 pm

Colorado Convention Center – 607

If you are active with your local section, be sure to join us for this annual event. You'll network with other local section leaders, hear more about SME's programs for local sections, and learn some local section "best practices" from your peers.

NEW MEMBER ORIENTATION & RECEPTION

Monday, February 20

5:00 pm – 6:30 pm

Colorado Convention Center – 109-113

Members who joined SME in 2016 or 2017 should plan on attending this reception to learn about the benefits of membership while networking with their peers. This is a great opportunity to gather information on how to maximize your SME membership experience while meeting many of the wonderful people in the industry.

RISING PROFESSIONALS SOCIAL

(Ticketed)

Monday, February 20

7:00 pm – 9:00 pm

Hyatt Regency Denver – Agate

Tickets: $30

SME Young Leaders will host a professional networking and social reception specifically for young industry professionals looking to meet other up-and-coming, like-minded individuals. Gather with young (and young at heart) industry professionals to catch up on each other's career development and networking opportunities. 2015 SME President Steve Gardner will also be giving a brief presentation on, "Reflections on a Career in Mining and How SME Helps."

SOCIAL FUNCTIONS
& DIVISION HIGHLIGHTS

SME/AIME AWARDS BANQUET

Sponsored by: Jenmar Corp

Wednesday, February 22

6:00 pm Cash Bar Reception
7:00 pm Banquet

Hyatt Regency Denver – Centennial Ballroom D-E

Tickets $95 Each / $950 Table of Ten

The 2017 SME Awards Banquet program is conducted by 2016 SME President Tim Arnold.

SPECIAL RECOGNITIONS:

Hoover Award: *Leonard Harris*

The following awards are presented or recognized:

AIME AWARDS

AIME Presidential Citation:
Debra J. Shields, Ponisseril Somasundaran

AIME Honorary Member:
Hugh B. Miller, Arthur A. Schweizer

Frank F. Aplan Award:
S A. Ravishankar

James Douglas Gold Medal:
William F. Riggs

Mineral Economics Award:
Ronald L. Lewis

Mineral Industry Education Award:
Hugh B. Miller

Erskine Ramsay Medal:
Vladislav Kecojevic

Robert H. Richards Award:
S A. Ravishankar

William L. Saunders Gold Medal:
Phillips S. Baker, Jr.

Charles F. Rand Memorial Gold Medal:
Harry M. (Red) Conger

Robert Earll McConnell Award:
Not Given This Year

Rossiter W. Raymond Award:
Aaron Noble

SOCIAL FUNCTIONS & DIVISION HIGHLIGHTS

(Continued)

SME AWARDS

Robert M. Dreyer Award:
Ronald L. Parratt

WAAIME Founders Day Award:
Jean O. Davin

Minerals Education Coalition (MEC) Leadership Award:
Corie Ekholm

MEC Organization Recognition Award:
SME Colorado Section

MEC Partnership Appreciation Award:
Amautas Mineros Association

President's Citation: Individual:
Harry M. Parker; Mark N. Savit

President's Citation for Local Section Service:
Neil & Camille Prenn

Ivan B. Rahn Education Award:
K. Marc LeVier; Raja V. Ramani

Syd S. Peng Ground Control in Mining Award:
Gregory J. Hasenfus

MEC Student Chapter Award:
SME Norwood Student Chapter – University of Kentucky

Outstanding Student Chapter Award:
Indian Institute of Technology (ISM)

Henry Krumb Lecturers:
Sean Dessureault; Donald Ewigleben; Donald Hulse;
Ihor Kunasz; Kramer Luxbacher; Moe Momayez; Aaron Noble;
Ebrahim Tarshizi; Stan Vitton; Joshua Werner

Past President's Plaque:
Timothy D. Arnold

SME Distinguished Members:
C. Dale Elifrits; D. Erik Spiller; Courtney A. Young

SME HIGHLIGHTS

EXHIBIT HALL GRAND OPENING RECEPTION

Sunday, February 19
4:00 pm – 6:00 pm
Colorado Convention Center – Hall A-C

SME FOUNDATION DINNER AND CASINO NIGHT

Sunday, February 19
6:00 pm Cocktails
7:00 pm Dinner, Awards, Dancing
Hyatt Regency Denver – Foyer and Centennial Ballroom D–H
Tickets $105 Each / $3,000 Table of Eight Sponsorship

EXHIBIT HALL LUNCHEON

Monday, February 20
11:30 am – 1:00 pm
Colorado Convention Center – Hall A-C

SOCIAL FUNCTIONS & DIVISION HIGHLIGHTS

(SME Highlights Continued)

WOMEN OF SME, WAAIME & WIM BREAKFAST

Tuesday, February 21
7:00 am – 9:00 am
Hyatt Regency Denver – Centennial A-B
Tickets $40

Diversity to Drive Business & Mentoring to Drive Career Development

PROGRAM AGENDA
7:30 am Welcoming
Keynote Speaker: *Why Mentoring is Important*
Mentoring Circles Activity
9:00 am Closing

Discussions around 'Workplace Diversity' typically focus on gender, race, ethnicity, sexual orientation, and culture. While those are important considerations for enhancing diversity in the service of improved business performance, diversity of thought is often overlooked as a key outcome and benefit of 'Workplace Diversity.' Differing perspectives on how we perceive things also are informed by our unique traits as individuals and can positively contribute to improved decision-making through productive debates that spur a comprehensive analysis and creative, out-of-the-box thinking. While 'Workplace Diversity' is increasingly becoming a 'buzzword' for today's leader across industries, including mining, 'Inclusion' needs to become part of our business lexicon to ensure leaders and employees actively embrace diversity and unleash the power it can bring to improved business results.

Our keynote speaker, Beatrice Opoku-Asare, Newmont Mining's Global Inclusion and Diversity Director will share her personal journey, challenge our thinking on diversity within the mining industry and present on the progress Newmont is making in its Global Inclusion and Diversity journey.

EXHIBIT HALL AFTERNOON SOCIAL

Tuesday, February 21
3:30 pm – 5:30 pm
Colorado Convention Center – Hall A-C

EXHIBIT HALL CONTINENTAL BREAKFAST

Wednesday, February 22
8:00 am – 9:30 am
Colorado Convention Center – Hall A-C

COAL & ENERGY DIVISION HIGHLIGHTS

The objectives of the Coal & Energy Division are:

1. Provide a means for cooperation and communication among professionals interested in coal and energy.
2. Promote the use of coal as a major source of energy.
3. Advance technologies in coal exploration, mining, and utilization through meetings, programs, publications, and education.
4. Create student interest in the coal and energy industries as a career opportunity.

COAL & ENERGY DIVISION LUNCHEON

Tuesday, February 21
Noon – 1:45 pm
Colorado Convention Center – Four Seasons Ballroom 2-3
Tickets $55
Speaker: Dr. Jessica Kogel

The following awards are presented or recognized:

Coal & Energy Division Distinguished Service Award:
Thomas A. Gray

Coal & Energy Division Past Chair Award:
Robert P. Kudlawiec

Howard N. Eavenson Award:
John C. Stankus

Erskine Ramsay Award:
Vladislav Kecojevic

Stefanko Best Paper Award:
William G. Kendall, Jr.; James D. Noll;
John A. Organiscak; David S. Yantek

J.W. Woomer Young Engineer Award:
Nikhil Gupta

SOCIAL FUNCTIONS & DIVISION HIGHLIGHTS

(Continued)

ENVIRONMENTAL DIVISION HIGHLIGHTS

The objectives of the Environmental Division are:

1. Provide a means for cooperation and communication among professionals in the minerals industry engaged in any aspect of the physical environment and its condition.
2. Promote safe and environmentally sound mining practices.
3. Create a forum for exchanging technical information, publishing technical papers, and organizing technical meetings/programs.
4. Encourage and promote education on the subjects related to these phases of the environment.

ENVIRONMENTAL DIVISION SILENT AUCTION

Tuesday, February 21
11:00 am – 4:00 pm
Colorado Convention Center – Exhibit Hall Booth # 1811

ENVIRONMENTAL DIVISION LUNCHEON

Sponsored by MWH (now a part of Stantec)
Tuesday, February 21
Noon – 1:30 pm
Colorado Convention Center – Four Seasons Ballroom 1
Tickets $55
Speaker: Patrick Pfaltzgraff

The following awards are presented or recognized:

Benefactor Award:
Marcus A. Wiley

Environmental Division Distinguished Service Award:
Liane T. S. George

Environmental Division Past Chair Award:
Patrick L. Gorman

SME/AIME Environmental Stewardship Award:
Timothy M. Dyhr

HEALTH & SAFETY DIVISION HIGHLIGHTS

The objectives of the Health & Safety Division are:

1. Enhance professional development of health and safety professionals in the mining industry.
2. Create a forum for exchanging technical information, publish technical papers and organize technical meetings and programming for the advancement of the best health and safety practices.
3. Build capacity across all mining sectors for the improvement of health and safety.
4. Promote health and safety as a profession within the mining industry and to increase and support student interest in health and safety.
5. Collaborate with other professional societies.

HEALTH & SAFETY DIVISION 5K FUN RUN

Monday, February 20
6:30 am
Cherry Creek Trail, meet in CCC Room 101
Tickets $35

(Entry fee includes race T-shirt and water. Participants should be done with the race in time to prepare for the SME Annual Conference Keynote address.)

HEALTH & SAFETY DIVISION BREAKFAST

Tuesday, February 21
7:30 am – 8:30 am
Colorado Convention Center – 607
Tickets $45

Speaker: Bruce Watzman

The Division will present awards for:

Operational Excellence:
Running Right Leadership Academy

Excellence in Research and Education:
Emily A. Sarver; Susan M. Moore

Health & Safety Division Past Chair Award:
Thomas A. Hethmon

SOCIAL FUNCTIONS & DIVISION HIGHLIGHTS

(Continued)

INDUSTRIAL MINERALS & AGGREGATES DIVISION HIGHLIGHTS

The objectives of the Industrial Minerals & Aggregates Division are:

1. Further the arts and sciences involved in the exploration, production, and use of industrial minerals and aggregates.
2. Facilitate the presentation, publication and discussion of professional papers.
3. Promote the exchange of ideas and information on subjects of mutual interest with other SME divisions and member societies of AIME.
4. Encourage student interest in industrial minerals as a career opportunity.

INDUSTRIAL MINERALS & AGGREGATES DIVISION LUNCHEON

Tuesday, February 21
Supporting Sponsors: Civil & Engineering Consultants, Golder Associates, Imerys and R. E. Janes Gravel
Noon – 1:45 pm
Colorado Convention Center – Four Seasons Ballroom 4
Tickets $55
Speaker: Ariel Hill-Davis

The following awards are presented or recognized:

Industrial Minerals & Aggregates A. Frank Alsobrook Distinguished Service Award:
Gary P. Tomaino

Industrial Minerals & Aggregates Division Past Chair Award:
Jerry Gauntt

Industrial Minerals & Aggregates Young Scientist Award:
Ebrahim Karimi-Tarshizi

Robert W. Piekarz Award – Aggregates:
Steven J. Stokowski

Robert W. Piekarz Award – Industrial Minerals:
K. Joe Garska, III

MINERAL & METALLURGICAL PROCESSING DIVISION HIGHLIGHTS

The objectives of the Mineral & Metallurgical Processing Division are:

1. Provide a means for cooperation and communication among industry professionals interested in the unit processes and operations of mineral and metallurgical processing.
2. Promote the advancement of mineral and metallurgical technology through related meetings and professional discourse.
3. Stimulate the preparation, reading, discussion and circulation of technical papers on mineral and metallurgical processing.

MINERAL & METALLURGICAL PROCESSING DIVISION AWARDS PLENARY SESSION

Sponsored by Moly-Cop USA LLC
Monday, February 20
2:00 pm – 4:30 pm
Colorado Convention Center – 705-709

The Mineral & Metallurgical Processing Division Annual Awards Plenary Session features lectures from the recipients of MPD's major awards.

Gaudin Lecture Award Recipient/Lecturer:
Gerald Luttrell
Industrial Applications of Advanced Process Engineering

Richards Lecture Award Recipient/Lecturer:
S A. Ravishankar
Pushing the Limits of Physical Separation and Processes with Chemistry

Wadsworth Lecture Award Recipient/Lecturer:
Fiona M. Doyle
Hydrometallurgy, Sustainability, and Economic Competitiveness – How Have the Decades Changed Our Thinking?

Presentation of Rong Yu Wan Ph.D. Dissertation Award
Qingqing Huang

MPD SCOTCH NIGHTCAP – SOCIAL FUNCTION & FUNDRAISER

Sponsored by Weir Minerals and UPG (Unified Purchasing Group)
Tuesday, February 21
8:00 pm – 11:00 pm
Hyatt Regency Denver – Capitol 1-4
Tickets $50

Proceeds from this event support MPD's scholarship and award funds, helping those who want to make a career in the industry, and recognizing those who have made extraordinary contributions to the industry. In addition to the scotch tasting, this event features light snacks, cocktails and live music. Each attendee receives two tasting tickets and one drink ticket to redeem during the event.

SOCIAL FUNCTIONS
& DIVISION HIGHLIGHTS

(Continued)

MINERAL & METALLURGICAL PROCESSING DIVISION LUNCHEON

Sponsored by Caid Industries, Moly-Cop USA LLC, Praxair Inc.
Wednesday, February 22
Noon – 1:45
Colorado Convention Center – Four Seasons Ballroom 1
Tickets $55
Speaker: Bob Kilborn

The following awards are presented or recognized:

Outstanding Young Engineer Award:
R. Nick Gow

Mill Man Poem Award (Past Chair):
Mark Jorgenson

Antoine M. Gaudin Award:
Gerald H. Luttrell

Robert H. Richards Award:
S A. Ravishankar

Arthur F. Taggart Award:
Jan D. Miller; Chen-Luh Lin

Milton E. Wadsworth Award:
Fiona M. Doyle

Presentation of Rong Yu Wan Ph.D. Dissertation Award
Qingqing Huang

STUDENT POSTER CONTEST

The winners of the Mineral & Metallurgical Processing Division's Student Poster Contest are announced. The poster entries are displayed in the lobby outside the ballroom before the luncheon, and the students are available to answer questions.

MINING & EXPLORATION DIVISION HIGHLIGHTS

The objectives of the Mining & Exploration Division are:

1. Provide a means for cooperation and communication among professionals engaged in the mining of metals, research, specialized aspects of mining, and exploration technologies.
2. Advance these industry segments by promoting and publishing papers, organizing meetings and programs, and encouraging education on subjects related to the mining and exploration of metals.

MINING & EXPLORATION DIVISION LUNCHEON AND SILENT AUCTION

Sponsored by KGHM International
Supporting Sponsor: Hitachi Mining Division
Wednesday, February 22
Noon – 2:00 pm
Colorado Convention Center – Four Seasons Ballroom 2-3
Tickets $55
Speaker: Robert W. Schafer

The following awards are presented or recognized:

Ben F. Dickerson Award:
Donald R. Taylor

Daniel C. Jackling Award:
Robert W. Schafer

Miner of the Year Award:
A. Clayr Alexander

Mining & Exploration Division Distinguished Service Award:
Thomas W. Camm

Mining & Exploration Division Past Chair Award:
James D. Humphrey

Outstanding Young Professional:
Melissa L. H. Martinie

Robert M. Peele Memorial Award:
Matthew V. Deutsch

Program Area Manager Awards:
Thomas W. Camm, Bradley M. Dunn, Vivien Hui, Gregory F. Sutton

William L. Saunders Gold Medal:
Phillips S. Baker, Jr.

Rock Mechanics:
Loren J. Lorig

SOCIAL FUNCTIONS
& DIVISION HIGHLIGHTS

(Continued)

WAAIME DIVISION HIGHLIGHTS

WAAIME is comprised principally of women involved in diverse activities in the mining sector, whose objective is to raise funds for the awarding of scholarships to mining engineering and earth sciences students at the undergraduate and graduate levels.

The purposes and goals of WAAIME are:

- To render service to the country and to the community through activities that pertain to the interests of the professions of mining, metallurgical and petroleum engineering.
- To promote interchange of ideas and work amongst members.
- To secure and maintain a fund for the purposes of voluntarily assisting promising young men and women to obtain a technical education in mining, metallurgical and petroleum engineering, or allied subjects.

WOMEN OF SME, WAAIME & WIM BREAKFAST

Tuesday, February 21
7:00 am
Hyatt Regency Denver – Centennial A-B
Tickets $40

Discussions around 'Workplace Diversity' typically focus on gender, race, ethnicity, sexual orientation, and culture. While those are important considerations for enhancing diversity in the service of improved business performance, diversity of thought is often overlooked as a key outcome and benefit of 'Workplace Diversity.' Differing perspectives on how we perceive things also are informed by our unique traits as individuals and can positively contribute to improved decision-making through productive debates that spur a comprehensive analysis and creative, out-of-the-box thinking. While 'Workplace Diversity' is increasingly becoming a 'buzzword' for today's leader across industries, including mining, 'Inclusion' needs to become part of our business lexicon to ensure leaders and employees actively embrace diversity and unleash the power it can bring to improved business results.

Our keynote speaker, Beatrice Opoku-Asare, Newmont Mining's Global Inclusion and Diversity Director will share her personal journey, challenge our thinking on diversity within the mining industry and present on the progress Newmont is making in its Global Inclusion and Diversity journey.

WAAIME DIVISION IRIS WHINNEN-OWEN SILENT AUCTION

Sunday, February 19 to Tuesday, February 21
During Exhibit Hall Hours
Colorado Convention Center – Exhibit Booth 2004

WAAIME 100TH ANNIVERSARY CELEBRATION & ALUMNI RECEPTION

Tuesday, February 21
5:30 pm – 7:30 pm
Centennial Ballroom, Hyatt Regency Denver – Centennial Ballroom D-H

Join WAAIME members, university groups, students, alumni and scholarship recipients in celebrating this momentous occasion during the 2017 SME Annual Conference & Expo.

Looking for your Student Alumni Reception at the Annual Meeting?

Look no further – The WAAIMEs are hosting your reception at their 100th Anniversary Celebration. WAAIME will provide a designated table for you and your fellow alumni to relax and catch up with your colleagues. Alumni from other mining and geoscience schools will be joining you for an evening of visual story-telling and socializing. Enjoy special hors d'oeuvres and libations, and receive a special memorabilia magazine, as we celebrate 100 years of successful philanthropic work of the women who, for more than 100 years, have provided significant support to the future leaders of the global mining community. Please RSVP today to your alumni chapter or to waaime@smenet.org.

The following universities will have gathering spaces during the reception:

University of Arizona
Colorado School of Mines
University of Kentucky Department of Mining Engineering
Michigan Technological University
Friends of Minnesota
Missouri University Science & Technology
Montana Tech
New Mexico Tech
University of Nevada, MaKay School of Earth Sciences & Engineering
Penn State
South Dakota School of Mines & Technology
University of Utah College of Mines & Earth Sciences
Virginia Tech
West Virginia University Mining Engineering

WAAIME FOUNDERS AWARD

Presented at the SME/AIME Awards Banquet
Wednesday, February 22
7:30 pm – 10:00 pm
Hyatt Regency Denver, Centennnial D-E

Recipient:
Jean O. Davin

STUDENT **ACTIVITIES**

SME/NSSGA STUDENT DESIGN COMPETITION (FINAL PRESENTATIONS)

Sunday, February 19
7:00 am – 2:00 pm
Hyatt Regency Denver – Capitol 5

The SME/NSSGA Student Design Competition is a two-phase, team-based aggregates-specific problem involving a technical design and an oral presentation. The technical design takes place during the first semester of the school year on each team's campus. It is designed to simulate an engineering project prepared by an engineering group for a company. Past problems have highlighted the challenges of mine planning, plant design, reserve modeling, and feasibility analysis.

SME STUDENT MEMBER ENGAGEMENT BREAKFAST

Sponsored by: Newmont Mining Corp
Sunday, February 19
8:30 am – 11:00 am
Hyatt Regency Denver – Capitol 4

The Newmont Student Member Engagement Breakfast was initiated in 2016 to increase student involvement in industry matters that directly affect them. Students are encouraged to participate in the breakfast, presentation and Q & A.

CATERPILLAR STUDENT FORUM AND RECEPTION

Sunday, February 19

1:00 pm – 3:00 pm

Colorado Convention Center – 605-607

The Forum provides a time for students to network with industry professionals and other students. Join us for a continuing tradition for SME Student Members and professionals.

MENTOR MEETING PLACE

Sunday, February 19

3:00 pm – 5:00 pm

Colorado Convention Center – 710-712

Please remember to enroll in the online mentor program and select the appropriate meeting. Once you identify your mentor or mentee, make arragements to connect during the 2017 SME Annual Conference & Expo and CMA's 119th National Western Mining Conference. We would love for you to come by the mentor meeting place to say "Hello!" We can assist you in signing-up online, however you are responsible for arranging a meeting with your mentor or mentee.

I ♥ Mining

Casino Royale

JOIN THE SME FOUNDATION FOR ITS

Annual Gala Dinner

Sunday, February 19, 2017
Centennial Ballroom | Hyatt Regency
Colorado Convention Center, Denver, CO

6:00 pm – 7:00 pm
Cocktail Reception & Silent Auction

7:00 pm – 11:00 pm
Dinner, Entertainment & Casino Games

SME
FOUNDATION™

YOUNG LEADERS

YOUNG LEADERS FIELD TRIP

Saturday, February 18
7:00 am – 5:00 pm
Climax Molybdenum Mine

Climax Molybdemun is a Freeport McMoRan Company. The Climax mine produces high-purity, chemical-grade molybdenum concentrates, which are typically further processed into value-added molybdenum chemical products. Located approximately 13 miles northeast of Leadville, Colorado, the Climax mine is a porphyry molybdenum deposit with molybdenite as the primary sulfide mineral. This mine began production in May of 2012, and includes a 25,000 metric ton-per-day mill facility.

Please bring your own PPE and money for lunch. The bus will be making a stop for attendees to purchase food. Buses depart Hyatt Regency Denver Lobby.

YOUNG LEADERS COMMITTEE MEETING

Sunday, February 19
3:00 pm – 5:00 pm
Hyatt Regency Denver – Capitol 4

Are you a leader in both your career and your community? If so then you might be SME Young Leader material! As a Young Leader you will be able to plan and create programs and events to help further develop your career and leadership skills with other young professionals. If you are interested in making a change, join us for our annual committee meeting and learn about our many leadership opportunities.

YOUNG LEADERS MENTORING LUNCHEON

Monday, February 20
11:00 am – 1:00 pm
Colorado Convention Center – 111
(ticketed)
Receive guidance and feedback from one of our industry experts as they share career experience and impressions of the current state of the industry with other young professionals. This year's speaker will be George Luxbacher, Principal of MELM Consulting LLC and 2008 President of Society for Mining, Metallurgy & Exploration.

RISING PROFESSIONALS SOCIAL

Monday, February 20
7:00 pm – 9:00 pm
Hyatt Regency Denver – Agate
(ticketed)

Gather with young (and young at heart) industry professionals to catch up on each other's career development and networking opportunities. The 2015 SME President Steve Gardner will also be giving a brief presentation on, "Reflections on a Career in Mining and How SME Helps."

PROFESSIONAL DEVELOPMENT HOURS

Available for 2017 SME Annual Conference Attendees

SME WILL OFFER PDH FOR ATTENDING SESSIONS AT THE SME ANNUAL CONFERENCE.

Those who are interested can register for this service. SME is offering a comprehensive, online internet product that simplifies the PDH verfication process for attendees. It puts attendees in control of their own session verification, tracking and certificate production. This will allow session attendees to use their own computers or dedicated onsite kiosks to record sessions in which they have participated and to print their own verification certificates. Those interested can register for this service for $25 at the registration desk.

2017 **EDUCATORS' FORUM**

SME ANNUAL CONFERENCE & EXPO

Saturday, February 19
3:00 pm – 5:00 pm
Colorado Convention Center – 601
C. Dale Elifrits, Convener
elifritsc@nku.edu

Successful Entry Level Employment in the Industry During "Tough" Times.

Representing the Hard Rock and Metal Mining Sector:
Betsy Johnson, Staffing Supervisor – College Recruiting
Freeport-McMoRan
Phoenix, AZ
602-345-5697
bjohnson3@fmi.com

Representing the Aggregates and Industrial Minerals Sector:
Kathryn (Katie) Kosloski, Foreman Trainee
Luck Stone – Goose Creek Plant
P.O. Box 4476
Leesburg, VA 20177
804-400-2591 Direct
804-400-2591 Mobile
KKosloski@luckstone.com

Mark Kelpe, Plant Manager
Luck Stone – Bealeton Plant
P.O. Box 239
Bealeton, VA 22712
571-233-0588 Direct
571-233-0588 Mobile
MKelpe@luckstone.com

Representing the Machinery Manufacturing Sector:
Chelsea Pomeroy, Marketing Representative
Caterpillar Global Mining – Surface Mining & Technology Division
901 W. Washington, CV4144
East Peoria, IL 61630
Office: +1-309-578-0696
Cell: +1-720-936-2088
Pomeroy_Chelsea_A@cat.com

University Faculty and Administration Thoughts:
Mike Nelson, Ph.D., Professor and Chair
Mining Engineering Department
William C. Browning Building, Rm 313
University of Utah
Salt Lake City, UT 84112
801-585-3064
mike.nelson@utah.edu

Update on the SME Ph.D. Fellowship and Faculty Grant Programs:
Courtney Young*, Ph.D., Q.P.*
Department Head and Prater Distinguished Professor
Metallurgical and Materials Engineering
School of Mines and Engineering
Montana Tech of The University of Montana
Butte, MT 59701-8997
406-496-4158
cyoung@mtech.edu

Questions and Answers – Panel Discussion

2016 **SME BOARD OF DIRECTORS**

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Thom Seal
Matt J. Blattman
Jamal Rostami
Barry Martin
Aaron Noble
Tara Davis, Staff Liaison

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MEC Partnership Appreciation Award:
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Outstanding Student Chapter: *Indian Institute of Technology (ISM)*

Syd S. Peng Ground Control In Mining Award: *Gregory J. Hasenfus*

President's Citation: *Neil & Camille Prenn, Harry Parker, Mark Savit*

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Energy Fuels is currently the 2nd largest uranium producer in the U.S. and holds three of America's key uranium production centers. The White Mesa Mill, located in Utah, is the only conventional uranium mill in production in the U.S. today. The Nichols Ranch ISR Project currently produces low-cost uranium in Wyoming. The Alta Mesa ISR Project is currently on care and maintenance in Texas. Energy Fuels also has the largest uranium resource portfolio in the U.S., a high-grade uranium/copper mine in development in Arizona, mines on standby in Colorado and

Utah, and mineral properties in various stages of permitting and development in a number of Western States.

Contact Information:
225 Union Blvd, Suite 600
Lakewood, CO 80228
Phone: (303) 974-2142
www.energyfuels.com

HOGAN LOVELLS US LLP

CMA Colorado Division of Reclamation & Safety Awards Luncheon Sponsor

Hogan Lovells is one of the world's premier providers of legal services to the mining industry. We advise mining and extractive businesses on a wide range of areas, from securities and merger and acquisition transactions to environmental, regulatory, health and safety, employment, and litigation matters. Our cross-disciplinary approach and our knowledge of and contacts with government agencies enable us to help clients operate globally and achieve their long-term business objectives.

We are a full-service, solutions-driven team, with significant depth of resources and genuine international breadth. We stay at the forefront of environmental and permitting issues related to federal public lands, Indian lands, and water and air quality, and understand the interests and tactics of a significant range of stakeholders including; governments, public, and private.

Contact Information:
1601 Wewatta St. Suite 900
Denver, CO 80202 USA
Phone: (303) 899-7300
www.hoganlovells.com/

HOLLAND & HART, LLP

CMA Annual Membership Meeting Sponsor

Holland & Hart has been a leading mining law firm since its founding in 1947. Holland & Hart has over 440 lawyers in 15 offices throughout the Mountain West and in Washington, D.C. In 2013, the firm was named Law Firm of the Year for Mining by U.S. News & World Report and Best Lawyers, and since 2007 has been recognized as a leading mining law firm by The International Who's Who of Mining Lawyers. From exploration through closure, our lawyers have broad experience advising clients on every aspect of mining operations throughout the United States and internationally.

Contact Information:
6380 South Fiddlers Green Circle, Suite 500
Greenwood Village, CO 80111 USA
Phone: (303) 290-1074
www.hollandhart.com

JACKSON KELLY PLLC

CMA Colorado Division of Reclamation & Safety Awards Luncheon Sponsor

Jackson Kelly PLLC's team of legal professionals are focused on meeting the rapidly changing needs of clients in Colorado and across the United States. The Denver attorneys bring the Firm's significant resources in support of its clients. Attorneys in the Denver office represent clients in several areas of law, including civil litigation, construction, environmental, government affairs, employment, business law and corporate transactions. Denver is also headquarters for Jackson Kelly's nationally recognized practice in occupational safety and health law. The office's clients include multiple industries including mining, construction, property development, information technology, and government entities.

Contact Information:

1099 18th Street Suite 2150
Denver, CO 80202, USA
Phone: (303) 390-0003
www.jacksonkelly.com

MOUNTAIN COAL COMPANY, LLC

CMA Environmental Stewardship Awards Banquet Sponsor

Arch Coal's Mountain Coal Company, LLC operates the West Elk Mine located in Gunnison County, Colorado, near the town of Somerset. Arch Coal, Inc. is one of the world's largest and most efficient coal producers. Its core business is providing U.S. power producers with cleaner-burning, low-sulfur coal for electric generation. Arch also exports coal for use in steel-making and electric power generation. Arch Coal contributes nearly 15% of America's coal supply. We have a leading position in every major U.S. coal basin. We're proud stewards of safety and the environment, and have amassed dozens of national and state awards for excellence. We are also a recognized leader in technology and innovation with Business Week's Web Smart 50, CIO 100 and Information Week 500.

Contact Information:

West Elk Mine
P.O. Box 591
Somerset, CO 81434, USA
Phone: (970) 929-2228

NEWMONT MINING CORP

CMA All Sessions Sponsor

Founded in 1921 and publicly traded since 1925, Newmont is a leading producer of gold and copper. Headquartered in Colorado, the Company has approximately 29,000 employees and contractors, with the majority working at managed operations in the United States, Australia, New Zealand, Peru, Indonesia and Ghana. Newmont is the only gold company listed in the S&P 500 index and in 2007 became the first gold company selected to be part of the Dow Jones Sustainability World Index. Newmont is an industry leader in value creation, supported by its leading technical, environmental, and health and safety performance.

Contact Information:

6363 S Fiddler's Green Cir, Ste 800
Greenwood Village, CO 80111 USA
Phone: (303) 863-7414
www.newmont.com

PERSHING GOLD CORP

CMA Environmental Stewardship Awards Banquet Sponsor

Pershing Gold (NASDAQ & TSX: PGLC) is an emerging gold producer whose primary asset is the Relief Canyon Mine in Pershing County, Nevada. Relief Canyon includes three historic open-pit mines and a state-of-the-art, fully permitted and constructed heap-leach processing facility. Pershing Gold is currently permitted to resume mining at Relief Canyon under the existing Plan of Operations.

Pershing Gold's landholdings cover approximately 25,000 acres that include the Relief Canyon Mine asset and lands surrounding the mine in all directions. This land package provides Pershing Gold with the opportunity to expand the Relief Canyon Mine deposit and to explore and make new discoveries on nearby lands.

Contact Information:
1658 Cole Blvd, Building 6, Suite 210
Lakewood, CO 80122 USA
Phone: 720-974-7254
www.pershinggold.com

PINNACOL ASSURANCE

CMA Colorado Division of Reclamation & Safety Awards Luncheon Audio-Visual Sponsor

Pinnacol Assurance is Colorado's leading provider of workers' compensation insurance, offering comprehensive coverage and proactive safety programs to more than 55,000 Colorado employers. Pinnacol employees spent over 35,000 hours keeping Colorado worksites safe and provided compassionate care to more than 40,000 Coloradans who were injured on the job. To recognize and encourage exceptional risk management, Pinnacol created the annual Circle of Safety award for Policy holders who excel in workplace safety and claims management. And through its community involvement program, Pinnacol actively supports local organizations that promote and enhance worksite and employee safety.

Contact Information:
7501 East Lowry Blvd
Denver, CO 80230, USA
Phone: (303) 361-4000
www.pinnacol.com

ROYAL GOLD, INC

CMA Colorado Division of Reclamation & Safety Awards Luncheon Sponsor

Royal Gold, Inc. acquires and manages precious metals royalty and stream interests, with a primary focus on gold. The Company's portfolio provides investors with a unique opportunity to capture value in the precious metals sector without incurring many of the costs and risks associated with mine operations. Royal Gold owns a large portfolio of producing, development, evaluation and exploration stage royalties and streams located in some of the world's most prolific gold regions. This successful business model generates strong cash flow and high margins with a lower cost structure, providing shareholders with a premium precious metals investment.

Contact Information:
1660 Wynkoop, #1000
Denver, CO 80202, USA
Phone: (303) 573-1660
www.royalgold.com

TRAPPER MINING, INC

CMA Colorado Division of Reclamation & Safety Awards Luncheon Centerpiece Sponsor

Trapper Mine began delivering coal to Craig Station in 1977. Current production levels are near 2 million tons per year. The mine is owned by four utility companies that have an interest in Craig Station. These utilities are Salt River Project, Tri-State Generation and Transmission, PacifiCorp and Platte River Power Authority. The hourly workforce is represented by the Operating Engineers Local No. 9. Trapper has established a reputation for excellence in the areas of safety, environmental stewardship and community involvement.

Contact Information:

P.O. Box 187
Craig CO, 81626, USA
Phone: (970) 824-4401

TRI-STATE GENERATION AND TRANSMISSION ASSOCIATION, INC.

CMA Environmental Stewardship Reception and Awards Banquet Sponsor

Founded in 1952 and headquartered in Westminster, Colo., Tri-State Generation and Transmission Association is the not-for-profit, cooperative wholesale power supplier to 43 member rural electric cooperatives and public power districts that collectively serve more than one million consumers across Colorado, Nebraska, New Mexico and Wyoming – a nearly 200,000 square-mile service territory. Tri-State employs more than 1,500 people and is governed by a board of 43 directors representing each of its member systems. The association operates more than 5,600 miles of high-voltage transmission line and generates power through a combination of baseload coal, intermediate and peaking natural gas power plants and renewable resources, including hydropower, wind and solar. In 2016, renewable resources are forecast to provide 25 percent of the energy Tri-State and its members deliver to rural consumers.

Contact Information:

PO BOX 33695
Denver, CO 80233
Phone: (303) 452-6111
www.tristategt.org

WAGNER EQUIPMENT CO.

CMA Colorado Division of Reclamation & Safety Awards Luncheon Sponsor

Wagner Equipment Co. is your Caterpillar dealer for Colorado, New Mexico and Far West Texas. Since 1976, Wagner sells and rents quality Cat machines used in heavy construction, building construction, mining, waste handling, paving, municipal and governmental applications, forestry, and more. Wagner's purpose is to serve the complete needs of their customers. Wagner conducts business with the highest level of integrity to ensure their continuing relationship with you. Wagner Equipment is committed to your future.

Contact Information:

18000 Smith Rd
Aurora, CO 80011 USA
Phone: (303) 739-3000
wleads@wagnerequipment.com
www.wagnerequipment.com

2017 EXHIBITOR HIGHLIGHTS

AT THE COLORADO CONVENTION CENTER

Exhibit Hall Opening Reception
Sunday, February 19
4:00 pm – 6:00 pm

Exhibit Hall Luncheon
Monday, February 20
11:30 am – 1:00 pm

Exhibit Hall Afternoon Social
Tuesday, February 21
3:30 pm – 5:30 pm

Exhibit Hall Continental Breakfast
Wednesday, February 22
8:00 am – 9:30 am

2017 EXHIBITORS

(As of January 20, 2017)

COMPANY NAME	BOOTH #
3D-P INC	1710
A.W. CHESTERTON CO, ARC EFFICIENCY & PROTECTIVE COATINGS	748
ABC INDUSTRIES, INC	1327
ABEL PUMPS L.P.	917
ACROW CORP OF AMERICA (ACROW BRIDGES)	1223
ACTION MINING SERVICES INC	304
ACZ LABORATORIES INC	1337
ADAM TECHNOLOGY/JOINTPYRAMID	2504
ADDONS, INC	1239
ADVANCED TERRA TESTING INC	2123
ADVANTAGE EARTH PRODUCTS, INC	1651
AECOM	1309
AERIX INDUSTRIES	1922
AFL	1351
AGAPITO ASSOCIATES INC	1237
AGRU AMERICA INC	2122
AGUDIO ROPEWAYS	1731
AIL MINING	1637
AIR-CURE INC	1848
AIRENG PTY LTD	2238
AIRGON LLC	2331
AIRPLACO EQUIPMENT (DIVISION OF MESA INDUSTRIES INC)	2424
ALASKA STRUCTURES, INC	339
ALLIED POWERS, LLC	337
ALTERNATIVE BLASTING CO	949
AMEC FOSTER WHEELER	1236
AMERICAN ENGINEERING TESTING, INC	438
AMERICAN EXPLORATION & MINING ASSOCIATION	937
AMERICAN INSTITUTE OF PROFESSIONAL GEOLOGISTS	1028
AMERICAN MINING INSURANCE GROUP	1222
AMERICAN PEAT TECHNOLOGY	817
AMR PEMCO, INC	418
ANDRITZ	723

COMPANY NAME	BOOTH #
ANVIL INTERNATIONAL	1109
APPLIED FLOW TECHNOLOGY	1429
AQSEPTENCE GROUP S.R.L.	2215
ARCADIS	1629
ARKEMA INC	1050
ASCENT GEOMATICS SOLUTIONS	2102
ASD INC - A PANALYTICAL CO	2045
ASSURED PARTNERS OF COLORADO	1030
ATLAS COPCO MINING ROCK EXCAVATION & CONSTRUCTION LLC	1822
AUTONOMOUS SOLUTIONS INC	706
AVIVID WATER TECHNOLOGY, LLC	2254
AWS DREDGE	842
BALDOR ELECTRIC CO	609
BAROID INDUSTRIAL DRILLING PRODUCTS	2119
BARR ENGINEERING CO	2129
BARRICK GOLD	648
BASF CORPORATION	1316
BDI WEAR PARTS	2113
BEKAERT MACCAFERRI UNDERGROUND SOLUTIONS	2322
BELT CONVEYOR GUARDING	705
BENETECH	2410
BGC ENGINEERING INC	345
BICO INC	2436
BIG-D CONSTRUCTION	744
BINDER+CO USA, INC	1040
BLAIR RUBBER COMPANY	649
BLUNDSTONE FOOTWEAR	1608
BOART LONGYEAR	1317
BOMBARDIER TRANSPORTATION	2511
BOY SCOUTS OF AMERICA JAMBOREE	1800
BRAHMA GROUP, INC	624
BRANNAN CONSTRUCTION COMPANY	1243
BRAY CONTROLS	709
BRITESPAN BUILDING SYSTEMS INC	727
BROOKVILLE EQUIPMENT CORP	2124
BRUKER	2003
BRUNEL CORP	2351

COMPANY NAME	BOOTH #
BRUNNER & LAY INC	449
BURLINGTON CIVIL, INC	1742
BV INTERNATIONAL, LLC	439
CAMESE - CANADIAN MINING SUPPLIERS	517
CANADIAN INSTITUTE OF MINING, METALLURGY & PETROLEUM (CIM)	2137
CANADIAN MINING JOURNAL	1939
CANARY SYSTEMS, INC	2244
CANTY	736
CAP LOGISTICS	1528
CARBON ACTIVATED CORP	651
CARLSON SOFTWARE	1717
CASCADE DRILLING L.P.	2449
CATERPILLAR INC - GLOBAL MINING	2228
CCC GROUP, INC	1227
CEMENTATION USA INC	2258
CENTRIC MINING SYSTEMS	523
CETCO	637
CH2M	1031
CHAMCO INDUSTRIES LTD	2049
CHECK-6, INC	1538
CHEMTREAT	1705
CHEVRON PHILLIPS CHEMICAL CO LP	1736
CIDRA MINERALS PROCESSING, INC	1118
CIVIL & ENVIRONMENTAL CONSULTANTS, INC (CEC)	1949
CLARIANT CORPORATION	2327
CLASSIC MOTORS, INC	328
CLEARSPAN FABRIC STRUCTURES	840
CLOUD PEAK ENERGY	543
COGEP MAINTENANCE SOFTWARE	849
COLOG BOREHOLE GEOPHYSICS	1129
COLORADO DIVISION OF RECLAMATION, MINING AND SAFETY	1342
COLORADO MINING ASSOCIATION (CMA)	1131
COLORADO SCHOOL OF MINES, DEPARTMENT OF MINING ENGINEERING	1439
COLUMBIA SOUTHERN UNIVERSITY	2105
CONETEC INC	729

COMPANY NAME	BOOTH #
CONTANGO STRATEGIES LIMITED	2205
CONTECH ENGINEERED SOLUTIONS	1042
CONTITECH NORTH AMERICA	1743
CONVERGENCE TRAINING	1728
CONVEYANCE SOLUTIONS BY CONTINENTAL	1648
CORNELL PUMP CO	2542
COYNE CHEMICAL	423
CPM ROSKAMP CHAMPION	704
CRADLE NORTH AMERICA INC	343
CRYSTALS UNLIMITED	1009
CUSTOM LININGS, INC	1625
CYTEC SOLVAY GROUP	1509
DAIGH COMPANY, INC - DA-MITE	2437
DALE FASTENER SUPPLY	839
DANIEL B STEPHENS & ASSOCIATES, INC (DBS&A)	1445
DASSAULT SYSTEMES	323
DATAMINE NORTH AMERICA INC	1145
DEISTER CONCENTRATOR, LLC	542
DELHUR INDUSTRIES, INC	1224
DERRICK CORPORATION	618
DESERT MOUNTAIN CORP	545
DESWIK	1148
DETOX AND TREATMENT CONSULTING, INC	751
DEZURIK/APCO/HILTON	623
DINO-LITE SCOPES (BIGC)	1805
DMC MINING SERVICES CORP	2636
DONALDSON COMPANY, INC	417
DOS SANTOS INTERNATIONAL, LLC	904
DOWL	1127
DRA AMERICAS INC	2548
DSI TUNNELING LLC	1315
DUECHTING PUMPS NORTH AMERICA, LP	2404
DYNO NOBEL	2240
ECO SOLUTION DISTRIBUTING	2202
EICKHOFF CORPORATION	422
EIRICH MACHINES	737

COMPANY NAME	BOOTH #
ENDURANCE BELTING	816
ENDURIDE CANADA USA INC	2223
ENERGY LABORATORIES, INC	2042
ENGART INC	2543
ENGINEERED FLUID, INC	2519
ENGINEERED PERFORMANCE VENTILATION SYSTEMS	2300
ENVIROCON, INC	1537
ENVIRONMENTAL PRODUCTS & APPLICATIONS	1740
ENVIROSUITE	2444
ERIEZ	1517
ERM (ENVIRONMENTAL RESOURCES MANAGEMENT)	1036
EUCLID CHEMICAL CO	2219
EURODRIP USA	2316
EUTECTIC CORPORATION	2416
EVOQUA WATER TECHNOLOGIES	1038
FEDERAL CONVEYOR COMPONENTS	602
FGX SEPTECH, LLC	1907
FILTRARTECH INC	845
FIRMATEK	2107
FIRST DRILLING	1530
FISHER CO	1048
FKC-LAKE SHORE	2448
FLANDERS INC	437
FLASHFILL SERVICES, LLC	1226
FLEXCO	1855
FLOTTWEG SEPARATION TECHNOLOGY, INC	1749
FLOWROX INC	1729
FLSMIDTH	1827
FLUID LIFE	1349
FLUID SYSTEMS, INC	2249
FLUIDMESH NETWORKS LLC	538
FORCE CONTROL INDUSTRIES, INC	848
FORMSPRAG LLC	310
FOTH INFRASTRUCTURE & ENVIRONMENT, LLC	622
FREEPORT-MCMORAN INC	348
G PLUS PLASTICS	2305

COMPANY NAME	BOOTH #
GANNETT FLEMING, INC	1807
GEA GROUP	2426
GENERAL CABLE CORP	1843
GENERAL ELECTRIC	1051
GENERAL KINEMATICS	2115
GEOKON, INC	1110
GEO-LOGIC ASSOCIATES	1544
GEOSHACK	1238
GEOTECH ENVIRONMENTAL EQUIPMENT, INC	1428
GEOTEMPS, INC / GEOPROS, INC	1536
GIW INDUSTRIES, INC (A KSB COMPANY)	1516
GLOBAL MINING STANDARDS AND GUIDELINES GROUP (GMSG)	2153
GMS MINE REPAIR & MAINTENANCE	1713
GOLD LEAF PLACER, LLC	1650
GOLDER ASSOCIATES	1929
GOMEZ INTERNATIONAL, INC	2549
GREAT BASIN INDUSTRIAL	2040
GREAT LAKES E & I	1524
GRINDEX PUMPS	2638
GROUNDPROBE NA LLC	2411
GSE ENVIRONMENTAL	2622
GUARDVANT INC	1350
GUY F ATKINSON CONSTRUCTION	2214
GW SYSTEMS	1755
H-2 ENTERPRISES	1242
HANDHELD	2428
HARRISON WESTERN	1424
HATCH	605
HAYWARD BAKER INC	1212
HAYWARD FLOW CONTROL	1849
HAZEN RESEARCH, INC	1340
HDR	2349
HEINTZMANN CORP	1408
HEPBURN ENGINEERING INC	822
HERCULES SEALING PRODUCTS	1341
HERRENKNECHT TUNNELLING SYSTEMS USA, INC	1217

COMPANY NAME	BOOTH #
HEXAGON MINING	1209
HILFIKER RETAINING WALLS	2036
HILLIARD CORP	836
HITACHI MINING DIVISION	1248
HI-TECH ROCKFALL CONSTRUCTION INC	2229
HOCHIKI AMERICA	1111
HONEYWELL INC	1724
HORIBA INSTRUMENTS, INC	2203
HOSE SOLUTIONS INC	1845
HOUSTON INTERNATIONAL INSURANCE GROUP	1325
HOUSTON POLYTANK	1950
HOWDEN NORTH AMERICA	2423
HUESKER INC	2142
HUNTSMAN	830
HYDROGEOPHYSICS INC	731
IDC INDUSTRIES	1802
IDENTEC SOLUTIONS	2405
IDENTIFIED TECHNOLOGIES	850
IDS DRILL	336
IMATECH	1045
INDEPENDENT MINING CONSULTANTS, INC	1417
INDIAN AFFAIRS - DIV OF ENERGY AND MINERAL DEVELOPMENT	1442
INDUSTRIAL INFO RESOURCES INC	2328
INDUSTRIAL SCIENTIFIC	843
INFLATABLE PACKERS INTERNATIONAL LLC	1943
INFOMINE INC	2628
IN-SITU INC	1441
INSTITUTO DE INGENIEROS DE MINAS DEL PERU (IIMP)	2418
INTERMOUNTAIN ELECTRONICS, INC	1029
INTERNATIONAL MINING	2626
INTERNATIONAL SOCIETY OF EXPLOSIVES ENGINEERS (ISEE)	2417
INTERTRACTOR AMERICA CORPORATION	1548
ISCO INDUSTRIES, INC	942
ISN	824
ITASCA INTERNATIONAL, INC	1945
ITW POLYMERS ADHESIVES NORTH AMERICA	1804

COMPANY NAME	BOOTH #
IWT	1942
IXOM WATERCARE	1339
JADCO MANUFACTURING, INC	1116
JEBCO INDUSTRIES INC	2227
JENIKE & JOHANSON	2206
JENNMAR CORP	516
JKTECH PTY LTD	1410
JOEST INC	1150
JOHNSON INDUSTRIES LTD	619
JOY GLOBAL	1216
JVI VIBRATORY EQUIPMENT	2141
K.R. KOMAREK INC	522
K4 INTEGRATION INC/TOPVU	2527
KAHUNA DESIGN	1443
KALENBORN ABRESIST CORP	2231
KANAWHA SCALES & SYSTEMS, INC	1251
KASE CONVEYORS	1113
KEMIRA	916
KIDDE FIRE SYSTEMS	2439
KLINGER IGI INC	1143
KLUBER LUBRICATION NA LP	2048
KNIGHT PIÉSOLD AND CO	1130
KNS COMMUNICATIONS CONSULTANTS	1642
KONNX INC	503
KOPPERN EQUIPMENT, INC	918
KRAFT POWER CORP	715
LASER TECHNOLOGY, INC	1540
LAYNE CHRISTENSEN CO	338
LEGACY BUILDING SOLUTIONS	1948
LEHIGH HANSON	445
LIEBHERR MINING EQUIPMENT CO	2023
LINE POWER MANUFACTURING	728
LINKAN ENGINEERING	925
LIPPMANN-MILWAUKEE	629
LPR CONSTRUCTION CO	1539
LSC ENVIRONMENTAL PRODUCTS, LLC	2155

COMPANY NAME	BOOTH #
LUFF INDUSTRIES LTD	1808
MAC PRODUCTS, INC	645
MACCAFERRI, INC	2325
MACKAY SCHOOL OF EARTH SCIENCES AND ENGINEERING	444
MAGNATION WATER TECHNOLOGIES	2505
MALA GEOSCIENCE USA, INC	2319
MAPEI CORPORATION	2054
MAPTEK	1409
MARTIN ENGINEERING	2104
MASTER DRILLING USA, LLC	2103
MATEK AMERICA INC	716
MATRIX DESIGN GROUP	1842
MATRIX SERVICE	1941
MATTERHORN FOOTWEAR	915
MCLANAHAN CORP	1610
MCLELLAN INDUSTRIES, INC	1839
ME ELECMETAL	2037
MEET MINNEAPOLIS CONVENTION & VISITORS ASSOCIATION	2442
MES MINING (DIV MINING ENVIRONMENTAL SERVICES)	1244
METCOM TECHNOLOGIES INC	2038
METSO	1737
MHE & MERRICK INDUSTRIES	1017
MICROMINE USA	1449
MIDWEST INDUSTRIAL SUPPLY, INC	1015
MILEX TECHNOLOGIES	2149
MILL MAN STEEL, INC	1230
MILLCREEK ENGINEERING CO	2624
MINCON	1249
MINE CABLE SERVICES CORP	416
MINE DEVELOPMENT ASSOCIATES	1936
MINEFILL SERVICES, INC	603
MINEMAX	1423
MINER ELASTOMER PRODUCTS	1448
MINERAL TECHNOLOGIES	1014
MINERO INC	1330
MINERS NEWS/MINING DIRECTORIES	1114

COMPANY NAME	BOOTH #
MINING & METALLURGICAL SOCIETY OF AMERICA (MMSA)	708
MINING EQUIPMENT, LTD	1323
MINING MAGAZINE	1937
MINING MEDIA INTERNATIONAL	1437
MISSOURI UNIVERSITY OF SCIENCE & TECHNOLOGY	1722
MIXTEC NORTH AMERICA	2139
MMD MINERAL SIZING (AMERICA) INC	2222
MOBILIZE RESCUE SYSTEMS	318
MONICO MONITORING, INC	2216
MONTANA TECH - SCHOOL OF MINES & ENGINEERING	548
MORETRENCH	941
MORRIS INTERACTIVE	2201
MOTION METRICS INTERNATIONAL CORP	2248
MPW INDUSTRIAL SERVICES	717
MST GLOBAL	1245
MTS SENSORS	628
MULTOTEC CANADA LTD	2252
MURRAY ENERGY CORPORATION	351
NALCO WATER	808
NATIONAL DRILLING ASSOCIATION	1906
NATIONAL EXPLORATION, WELLS & PUMPS	1123
NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY & HEALTH	2237
NATIONAL STONE, SAND & GRAVEL ASSOCIATION (NSSGA)	631
NATURAL CREATIONS	529
NAYLOR PIPE CO	1108
NELSON WILLIAMS LININGS, INC	750
NETAFIM USA	2330
NETZSCH PUMPS NORTH AMERICA, LLC	2510
NEW MEXICO INSTITUTE OF MINING & TECHNOLOGY	738
NEWFIELDS MINING & DESIGN	1426
NEWMONT MINING CORP	448
NEXANS AMERCABLE	1231
NEXOM	2144
NICHOLSON CONSTRUCTION	1039
NIDEC INDUSTRIAL SOLUTIONS	342
NIGHTSTICK BY BAYCO PRODUCTS	1444

COMPANY NAME	BOOTH #
NORDIC LIGHTS NA, INC	2419
NORDMIN ENGINEERING LTD	2211
NORMET AMERICAS, INC	2044
NPK CONSTRUCTION EQUIPMENT	2053
OI ANALYTICAL - A XYLEM BRAND	1513
OLYMPUS	1240
OPEN LOOP ENERGY, INC	2339
OREMAX	908
ORIGINAL CREATIONS INC	2308
OUTOTEC (CANADA) LTD	1609
PALL CORP	928
PANALYTICAL	2043
PATERSON & COOKE USA, LTD	553
PENN STATE UNIVERSITY	442
PENNONI	2148
PEX INDUSTRIAL PIPING SOLUTIONS	2314
PHOENIX CONVEYOR BELT SOLUTIONS	823
PHOENIX PRODUCTS COMPANY INC	714
PINTSCH BUBENZER	826
PITEAU ASSOCIATES ENGINEERING LTD	1541
PLASTICON COMPOSITES	643
POCOCK INDUSTRIAL, INC	1823
POLYCORP LTD	615
POLYDECK SCREEN CORP	2528
PORCUPINE CANVAS MANUFACTURING	319
POWER MOTIVE CORP	1144
PRECISION LIGHT AND AIR PTY LTD	2538
PRECISION PULLEY & IDLER	1616
PREDICTIVE SAFETY	1022
PRESTO GEOSYSTEMS	1019
PROCESSBARRON	745
PROCON TECHNOLOGIES INC	1326
PROMINE	1638
PSI DIGITAL IMAGING SOLUTIONS	902
PUMPACTION	1723
PUROLITE CORPORATION	919

COMPANY NAME	BOOTH #
PUTZMEISTER SHOTCRETE TECHNOLOGY	1708
QSP PACKERS, LLC	2531
QUADRA CHEMICALS INC	828
QUEEN'S UNIVERSITY	550
QUINN PROCESS EQUIPMENT CO	1522
R.S.T. INSTRUMENTS LTD	2324
RAIL-VEYOR TECHNOLOGIES GLOBAI INC	2343
RAISEBOR - A DIVISION OF COWIN & CO, INC	837
RAM ENTERPRISE, INC	722
RAMBOLL ENVIRON	2545
RANTEC CORP	948
RAPAT CORPORATION	1750
RAPIDBIZAPPS	702
RAPID FIRE PROTECTION INC	742
RDO INTEGRATED CONTROLS	1938
REDAELLI TECNA SPA	2516
REI DRILLING, INC	2512
RENISHAW INC	1016
RENOLD	939
RESOURCE WEST	2648
RESPEC	317
REYNOLDS ADVANCED MATERIALS	1043
RICHWAY INDUSTRIES	2318
RICHWOOD	1716
ROCKTECH USA, INC	719
ROCKY MOUNTAIN COAL MINING INSTITUTE	1228
ROCKY MOUNTAIN FABRICATION	1730
ROGERS EQUIPMENT SALES, INC	1128
ROSCOE POSTLE ASSOCIATES INC	1328
RPS COMPOSITES INC	829
RSG INC	1709
RUEN DRILLING, INC	1636
RULMECA CANADA LIMITED	811
RULMECA CORPORATION	809
RUNGEPINCOCKMINARCO	1117
RUT LLC	2055

COMPANY NAME	BOOTH #
SABIA, INC	2604
SALEM-REPUBLIC RUBBER CO	910
SAMINCO INC	923
SAMUEL ENGINEERING, INC	2348
SASKATCHEWAN RESEARCH COUNCIL	2304
SASKATCHEWAN TRADE AND EXPORT PARTNERSHIP	2302
SCANTECH INTERNATIONAL PTY LTD	630
SCHAUENBURG FLEXADUX CORP	1136
SCHENCK PROCESS MINING NA	2612
SCHEUERLE FAHRZEUGFABRIK GMBH	2616
SCHISSLER ENGINEERING LLC	1703
SCHREIBER LLC	1641
SCHURCO SLURRY PUMPS	844
SCHWEITZER ENGINEERING LABORATORIES, INC	1026
SCHWING BIOSET INC	831
SEMPERTRANS FRANCE BELTING TECHNOLOGY	814
SENSEMETRICS	617
SEPOR INC	749
SEPRO MINERAL SYSTEMS	2317
SGS MINERALS SERVICES	1422
SHAFT DRILLERS INTERNATIONAL	1149
SHOCO OIL INC	1141
SHOTCRETE TECHNOLOGIES, INC	2536
SICK	2523
SIEMAG TECBERG, INC	718
SIPI METALS CORP	324
SIZETEC, INC	1905
SLIDEMINDER - CALL & NICHOLAS INSTRUMENTS INC	909
SMARTCAP LLC	2313
SME FOUNDATION	1811
SMI EVAPORATIVE SOLUTIONS	2218
SMITHCO MFG	936
SOCIETY FOR MAINTENANCE & RELIABILITY PROFESSIONALS (SMRP)	638
SODERN	943
SOILWORKS	945
SONFILL LLC	1344

COMPANY NAME	BOOTH #
SOTRAFA SA	2050
SOUTH DAKOTA SCHOOL OF MINES	537
SOUTHWIRE CO	2208
SPECTRAL EVOLUTION	1142
SPENDRUP FAN CO	1137
SPEX SAMPLEPREP & KATANAX	519
SPLIT ENGINEERING	1414
SPRUNG STRUCTURES	308
SPX FLOW, INC	1008
SRK CONSULTING (US), INC	1436
SRS CRISAFULLI, INC	2209
ST EQUIPMENT & TECHNOLOGY LLC	557
STANCOR, INC	644
STANTEC - MWH	1523
STARKEY & ASSOCIATES, INC	536
STEINERT US	301
STEWART BROTHERS DRILLING CO	2337
STONHARD	1904
STRATA PRODUCTS WORLDWIDE, LLC	2311
SULZER PUMP SOLUTIONS INC	1549
SUNSET MANUFACTURING	1748
SUPERIOR INDUSTRIES	2649
SURECRETE INC	2537
SVENDBORG BRAKES USA, INC	312
SWCA ENVIRONMENTAL CONSULTANTS	1812
SY-KLONE INTERNATIONAL	2443
SYMPATEC INC	1345
SYNTRON MATERIAL HANDLING	1617
SYSCAD	741
TAKRAF USA, INC	1023
TDC, LLC	2438
TEAM MIXING TECHNOLOGIES, INC	2125
TECHNICAL TRANSLATION SERVICES	805
TELSMITH, INC	2642
TEMA ISENMANN INC	2350
TENCATE GEOTUBE	316
TENSAR INTERNATIONAL CORPORATION	322

COMPANY NAME	BOOTH #
TERRA SONIC INTERNATIONAL	1640
TERRASOURCE GLOBAL	2430
TESCAN USA INC	810
TESSENDERLO KERLEY, INC	710
TESTAMERICA	2529
TETRA TECH	2530
THE DOE RUN CO	349
THE MINERAL LAB, INC	1225
THE MINING RECORD	1208
THE QUIKRETE COMPANIES	1343
THE REINFORCED EARTH COMPANY	1037
THERMO FISHER SCIENTIFIC	1322
THYSSENKRUPP INDUSTRIAL SOLUTIONS (USA), INC	1529
TIC - THE INDUSTRIAL CO/KIEWIT MINING GROUP	1336
TIMBERLINE DRILLING, INC	2109
TIOGA AIR HEATERS	1655
TITAN ENVIRONMENTAL USA LLC	951
TLT-TURBO, INC	1649
TONS PER HOUR, INC/JINGJIN ENVIRONMENTAL	327
TOTAL POWER, INC	1837
TOTAL SPECIALTIES USA INC	1622
TRAMAC CORPORATION	743
TRAPBAG	1241
TRICON WEAR SOLUTIONS	419
TRIMBLE	1643
TRITON ENVIRONMENTAL	1542
TSURUMI PUMP	927
TUBE-MAC PIPING TECHNOLOGIES	436
TUNNELVIEW TECHNOLOGIES	249
TUNNEL RADIO	639
TURNKEY PROCESSING SOLUTIONS	2326
TWIN CITY CLARAGE, LLC	1348
U.S. GEOLOGICAL SURVEY (USGS)	2212
UE SYSTEMS INC	539
ULMA CONVEYOR COMPONENTS	2517
ULTRA TECH PIPE	1841
UNITED CENTRAL INDUSTRIAL SUPPLY	1331
UNIVAR USA INC	2539
UNIVERSITY OF ALASKA FAIRBANKS	344

COMPANY NAME	BOOTH #
UNIVERSITY OF ARIZONA MINING AND GEOLOGICAL ENGINEERING	1416
UNIVERSITY OF KENTUCKY DEPARTMENT OF MINING ENGINEERING	451
UNIVERSITY OF UTAH, MINING ENGINEERING DEPARTMENT	544
USA ENVIRONMENT LP	1138
VALLEY FORGE & BOLT MANUFACTURING CO	2236
VAN GORP CORPORATION	2143
VELODYNE	1140
VEOLIA WATER TECHNOLOGIES	2429
VERMEER CORP	1041
VICTAULIC CO	1923
VIRGINIA TECH DEPARTMENT OF MINING & MINERALS ENGINEERING	549
VOITH TURBO INC	802
VORTEX	2610
WAAIME	2004
WABI IRON AND STEEL	1711
WAGNER EQUIPMENT CO	1438
WATSON-MARLOW FLUID TECHNOLOGY GROUP	2152
WEG ELECTRIC CORP	1049
WEIR MINERALS - NORTH AMERICA	2029
WEST RIVER CONVEYORS & MACHINERY CO	1701
WEST VIRGINIA UNIV DEPT OF MINING ENGINEERING	443
WESTECH ENGINEERING, INC	2028
WESTERN CULTURAL RESOURCE MANAGEMENT, INC	1623
WESTERN ENVIRONMENTAL TESTING LAB (WETLAB)	912
WESTERN SMALL MINERS ASSOCIATION	1543
WESTPRO MACHINERY INC	1828
WILEY CONSULTING, LLC	1430
WILLOWSTICK TECHNOLOGIES LLC	1744
WIRTGEN AMERICA	1431
WOLF POINT ENGINEERS AND CONTRACTORS	642
WOMEN'S MINING COALITION	1944
WORLD COAL	2618
WSP | PARSONS BRINCKERHOFF WATER SERVICES	652
YELLOW JACKET DRILLING SERVICES	1545
ZONGE INTERNATIONAL, INC	636

2018 SME EXHIBIT **BOOTH SALES**

- Exhibit booth space selection for the **2018 SME Annual Conference & Expo and the 91st Annual Meeting of the SME-MN Section** is based on a priority point system.
- Each exhibitor has an assigned space selection date and time appointment.
- Your appointment date and time was provided to you in your on-site Exhibitor Packet. Please be on time for your meeting!
- Remaining space will be assigned on a first-come, first-served basis starting at approximately 11:15 am on Wednesday, February 22, 2017.

ON-SITE EXHIBIT SALES DATES:

Monday, February 20, 2017
3:00 pm – 5:00 pm

Tuesday, February 21, 2017
10:00 am – 5:00 pm

Wednesday, February 22, 2017
8:00 am – 11:00 am

LOCATION:

SME Exhibit Sales and Operations Office
Colorado Convention Center,
Exhibit Hall B, Back Center of Hall

2018 SME ANNUAL CONFERENCE & EXPO AND THE 91ST ANNUAL MEETING OF THE SME-MN SECTION

February 25 – 28, 2018
Minnesota Convention Center,
Minneapolis, Minnesota, USA

2018 CMA EXHIBIT **BOOTH SALES**

Exhibit booth space selection for the **2018 CMA 120th National Western Mining Conference** is based on a first come, first served basis starting on Monday February 20, 2017 at 3:00 pm.

ON-SITE EXHIBIT SALES DATES:

Monday, February 20, 2017
3:00 pm – 5:00 pm

Tuesday, February 21, 2017
10:00 am – 5:00 pm

Wednesday, February 22, 2017
8:00 am – 11:00 am

LOCATION:

CMA Exhibit Sales Office
Colorado Convention Center
Exhibit Hall B, Back Center of Hall

COLORADO MINING ASSOCIATION 120TH NATIONAL WESTERN MINING CONFERENCE

April 2 – 5, 2018
Colorado Convention Center
Denver, Colorado USA

COLORADO CONVENTION CENTER
FLOOR MAP

Creating VALUE
in a cyclical environment

SME 2017 SME ANNUAL CONFERENCE & EXPO

CMA 119th NATIONAL WESTERN MINING CONFERENCE

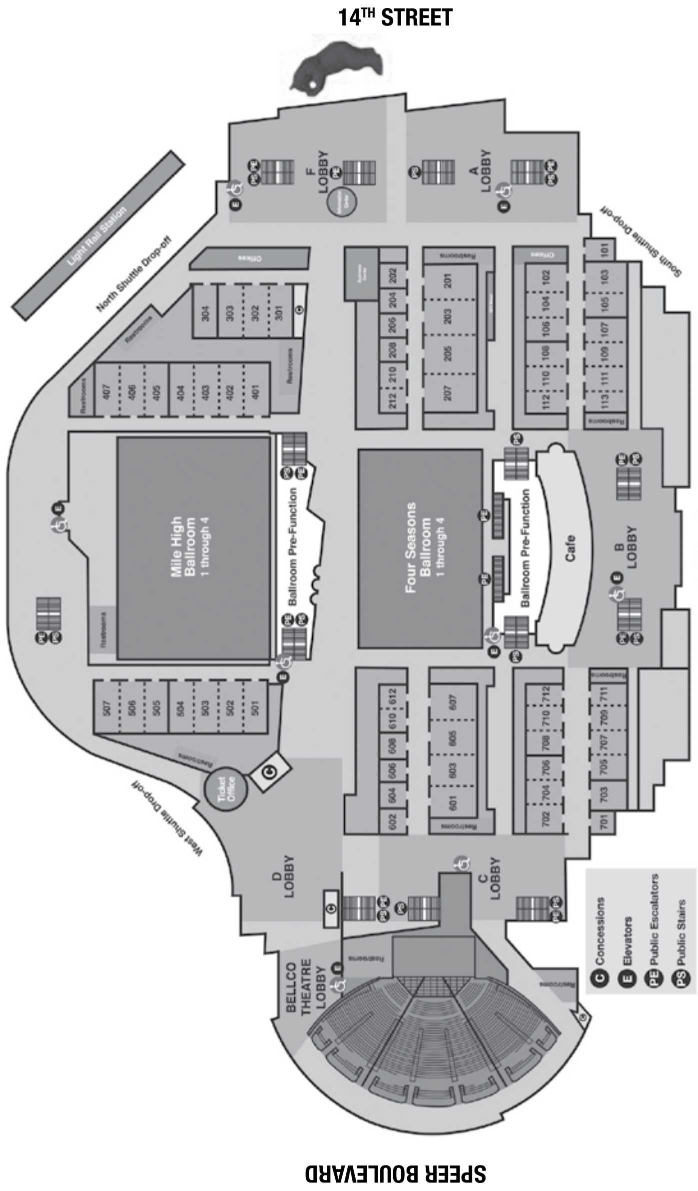
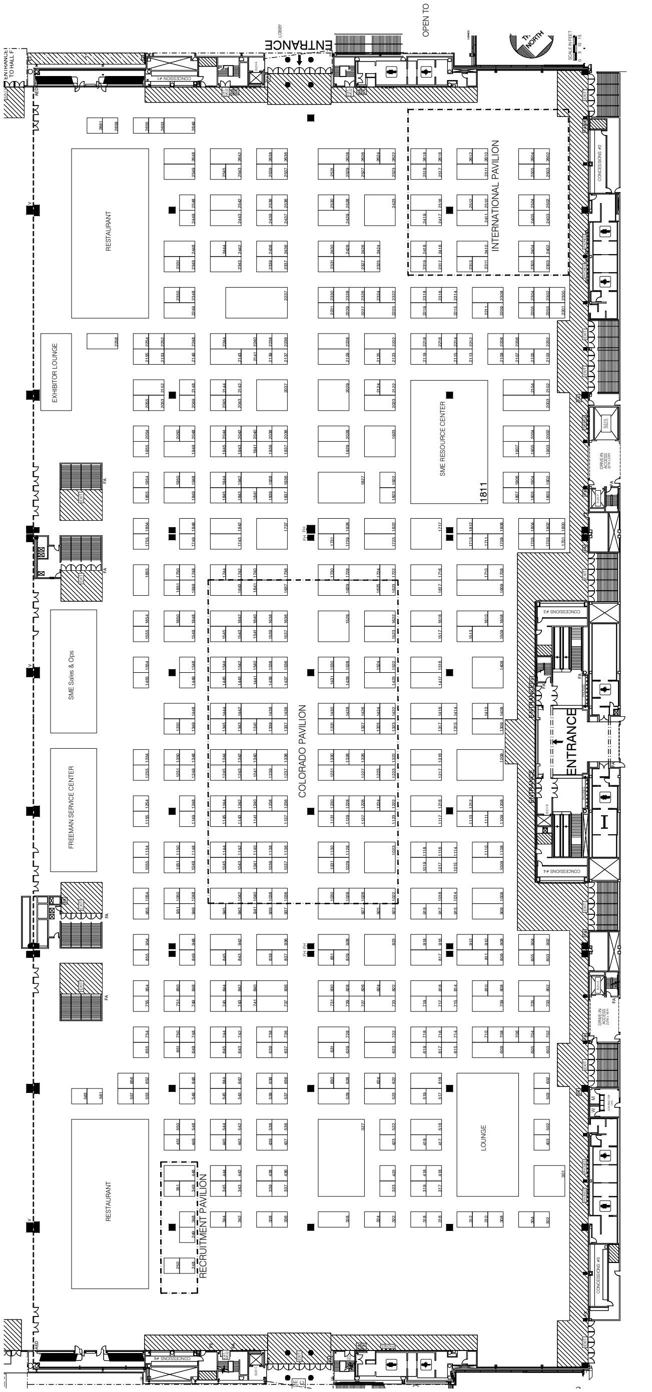

14TH STREET
F LOBBY
A LOBBY
B LOBBY
C LOBBY
D LOBBY
Light Rail Station
North Shuttle Drop-off
South Shuttle Drop-off
West Shuttle Drop-off
Offices
Restrooms
304 303 302 301
407 406 405 404 403 402 401
202 204 206 208 210 212
201 203 205 207
102 104 106 108 110 112
101 103 105 107 109 111 113
Mile High Ballroom 1 through 4
Ballroom Pre-Function
Four Seasons Ballroom 1 through 4
Ballroom Pre-Function
Cafe
507 506 505 504 503 502 501
Ticket Office
602 604 606 608 610 612
601 603 605 607
702 704 706 708 710 712
701 703 705 707 709 711
BELLCO THEATRE LOBBY
C Concessions
E Elevators
PE Public Escalators
PS Public Stairs
SPEER BOULEVARD

EXHIBIT FLOOR MAP

Creating VALUE
in a cyclical environment

SME 2017 SME ANNUAL CONFERENCE & EXPO

CMA 119th NATIONAL WESTERN MINING CONFERENCE


ENTRANCE
OPEN TO
NORTH
RESTAURANT
EXHIBITOR LOUNGE
SME Sales & Ops
FREEMAN SERVICE CENTER
COLORADO PAVILION
INTERNATIONAL PAVILION
SME RESOURCE CENTER
1811
LOUNGE
RECRUITMENT PAVILION
ENTRANCE
RESTAURANT

COLORADO MINING

Colorado Mining Association's 119th National Western Mining Conference & Exhibition

All CMA Sessions sponsored by Newmont Mining Corporation

Monday, February 20, 2017

Mining in Colorado – Creating Value in Coal: A Colorado Perspective

1:30 pm – 4:00 pm **Room 710/712**

Chairman: James Mattern, President, Trapper Mining Inc., Craig, Colorado

- ***Challenges Facing the U.S. Coal Industry: A Colorado Perspective***, James Mattern, President & General Manager, Trapper Mining Inc., Craig, Colorado
- ***The Outlook for Coal in International Markets***, Robert Burnham, President, Burnham Coal, LLC, Arvada, Colorado
- ***Survive & Advance: Mining Process at Colowyo D***, Chris McCourt, Mine Manager, Elk Ridge Mining & Reclamation, LLC, Colowyo Coal Company L.P., Meeker, Colorado and Drew Kramer, Senior External Affairs Advisor, Tri-State Generation and Transmission Association, Denver, Colorado
- ***Federal Coal Royalties, the Lease Moratorium and Its Impact on Colorado***, Trent Peterson, President & General Manager, GCC Energy, LLC, Hesperus, Colorado
- ***Session Wrap-Up and Late-Breaking Developments*** Stan Dempsey, Jr., President, Colorado Mining Association, Denver, Colorado

CMA Annual Meeting of the Members and the Board of Directors

Sponsored by Holland & Hart, LLP

4:00 pm **Room 710/712**

- ***The Chairman's Report*** James Mattern, CMA Chairman
- ***President's Annual Report*** Stan Dempsey, Jr., CMA President
- ***Election of Officers and Directors***

Tuesday, February 21, 2017

Mining in Colorado: Creating Sustainable Value in Hardrock and Metals

9:00 am **Room 710/712**

Chairman: Charles Rech,
C. W. Rech & Company, Littleton, Colorado

- ***Newmont CC&V: 18th Month Status Update***, Matthew Fein, Mine Manager, Newmont Cripple Creek and Victor Gold Mining Company, Victor, Colorado
- ***Continuous Improvement***, Chris Allen, Mine Manager, Colorado Administration, Climax Molybdenum Company (a Freeport-McMoRan Company), Leadville, Colorado
- ***Gypsum and the Housing Market***, Jared Rhea, Mine Superintendent, American Gypsum Company, LLC, Eagle Gypsum Mine, Gypsum, Colorado
- ***Global Uranium Supply Risk - Is History Repeating?***, Mark Chalmers, Chief Operating Officer, Energy Fuels Inc., Lakewood, Colorado

Regulation, Legislation and Policy Challenges: State and National

2:00 pm **Room 710/712**

Chairman: Bernard "Barney" Guarnera, President, Broadlands Mineral Advisory Services, Las Vegas, Nevada

- ***SME's Role to Successfully Engage the SEC to Modernize Industry Guide 7***, Ian Douglas, Group Executive Value Assurance, Newmont Mining Corporation, Greenwood Village, Colorado
- ***Finally, A Modern Industry Guide 7: The SEC Proposes New Property Disclosure Requirements for Mining Registrants***
  - Bernard Guarnera, President, Broadlands Mineral Advisory Services
  - Kenneth Sam, Co-Chair, Mining Industry Group, Dorsey & Whitney, Denver, Colorado
  - Jason Brenkert, Partner, Dorsey & Whitney, Denver, Colorado

Colorado Mining Association's 119th National Western Mining Conference & Exhibition – *continued*

Tuesday, February 21, 2017

CMA Environmental Stewardship Awards Banquet

Sponsored by Anglo Gold Ashanti North America, Inc.; Bowie Resource Partners, LLC; Mountain Coal Company, LLC; Pershing Gold Corporation; Tri-State Generation and Transmission Asociation, Inc.

Hyatt Regency at the Colorado Convention Center
Centennial Ballroom A – C

6:00 pm – 7:00 pm ***Reception***
7:00 pm – 9:30 pm ***Dinner, Program and Awards***

Banquet Presentation: The 2016 Elections and Beyond, What a Long Strange Trip It's Been

Richard Wadhams, Political Consultant,
Littleton, Colorado

Presentation of Awards

Wednesday, February 22, 2017

Challenges and Solutions in Mining

9:00 am **Room 710/712**

Chairman: Stuart A. Sanderson, Past President, Colorado Mining Association, Stuart A. Sanderson, LLC, Lone Tree, Colorado

- ***Good Samaritan Reform: The Path Forward,*** Laura Skaer, Executive Director, American Exploration & Mining Association, Spokane, Washington
- ***Seeking Solutions in Addressing Legacy Sites***, Patricia Limerick, Faculty Director & Chair of the Board of Directors, Center of the American West, University of Colorado, Boulder, Colorado
- **Collaborative Solutions in Historic Preservation**, Jeff Campbell, Senior Environmental Coordinator, Newmont Mining Corporation's Cripple Creek & Victor Gold Mining Company, Victor, Colorado and Rachael Nickless, Environmental Protection Specialist II, Colorado DRMS, Denver, Colorado
- ***A Collaborative Approach to Mine Reclamation,*** Jason Willis, Mine Restration Project Manager, Trout Unlimited, Salida, Colorado

CMA/Colorado Division of Reclamation, Mining & Safety Closing Awards Luncheon

Colorado Convention Center
Four Seasons Ballroom 4

Sponsored by Climax Molybdenum Company (a Freeport-McMoRan Company); Hogan Lovells US LLP; Jackson Kelly PLLC; Royal Gold, Inc.; Wagner Equipment Co.

11:45 am

Speaker: Robert Randall, Executive Director, Colorado Department of Natural Resources, Denver, Colorado

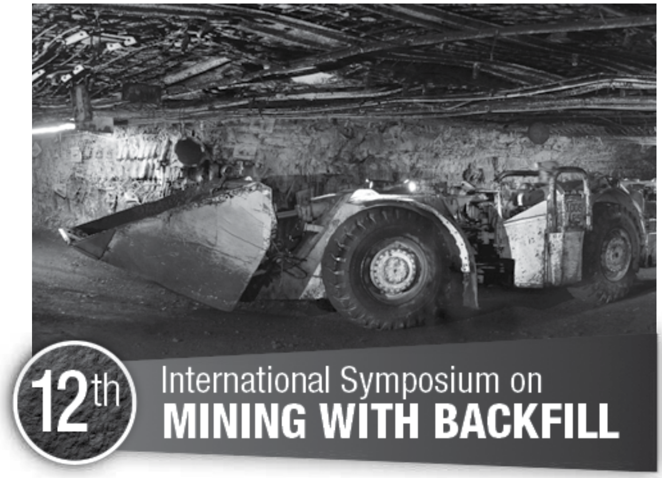
11:45 am ***Doors Open***
Noon ***Lunch***

Mine Emergency Risk/Readiness Self-Assessments – a Proactive Approach

2:00 pm **Room 710/712**

William C. York-Feirn, Director, CDRMS Mine Safety & Training Program, Colorado Division of Reclamation, Mining & Safety, Denver, Colorado and David Stalfort, Senior Director, ABS Group, Inc., Arlington, Virginia

Presentation of Awards



INTERNATIONAL SYMPOSIUM ON
MINING WITH BACKFILL

TECHNICAL PROGRAM

MONDAY, FEBRUARY 20, 2017

MORNING

9:00 am Room 603

Geomechanics

Chair*: Matt Helinski, Outotec*

9:00 am
Introductions

9:05 am
Liquefaction Potential of Cemented Paste Backfill under Dynamic Loads
Introduction by Panel Chair:
M. Shahsavari and M. Jafari, University of Toronto, ON, Canada; R. Moghaddam, Golder Associates, Mississauga, ON, Canada and M. Grabinsky, University of Toronto, ON, Canada

Cemented paste backfill (CPB) is the emerging trend in integrated mine tailings management. CPB consists of mine tailing, binder agents, and water that provides ground support for underground openings known as stopes. CPB has tight characteristics and a very high delivery rate compared to other backfilling materials such as rockfill. Once placed in a stope, CPB is generally considered as a loose, saturated granular soil at its early stage of binder hydration. Therefore, it might be prone to liquefaction if subjected to static or dynamic loadings. CPB liquefaction would lead to the application of excessive loads on the stope barricade and hence barricade failure. CPB liquefaction is much more complicated that the conventional liquefaction analysis of granular materials such as sand. Hydration and confined environment of a stope are a couple of these complicating factors in addition to the type of input ground motions (i.e., earthquakes vs mining-induced seismic loads). To be able to establish a design procedure, CPB liquefaction analysis must be done first using the conventional geotechnical earthquake engineering concepts. The current state of practice assumes that once the unconfined compressive strength of CPB reaches 100 kPa, the material is non-liquefiable.In this paper, first a non-linear time domain ground response analysis is performed using FLAC3D. The time dependent material properties due to binder hydration are incorporated into the analysis. FLAC3D results are then compared with the one dimensional equivalent linear analysis results using SHAKE2000. The induced shear stresses are then compared with the laboratory obtained cyclic shear resistances to identify the regions of backfilled CPB that are prone to liquefaction.

9:25 am

In Situ Performance of Cemented Paste Backfill at the Lucky Friday Mine

J. Seymour, M. Raffaldi, and H. Abraham, National Institute for Occupational Safety and Health, Spokane, WA; J. Johnson, University of Utah, Salt Lake City, UT and E. Zahl, Contractor, Spokane, WA

In cooperation with the Hecla Mining Company, NIOSH researchers have developed effective methods for monitoring the in situ performance of cemented paste backfill during underhand cut-and-fill mining. Robust and reliable instruments were installed at eight locations in two production stopes prior to backfilling and monitored over a two-year period through five undercut advances. Horizontal pressures up to 5.5 MPa (798 psi) were measured in the paste fill along with stope closures of more than 50 cm (19.7 in). From the instrument data, the in situ stress vs. strain behavior of the paste fill was analyzed, providing an average in situ modulus of deformation of about 3.62 GPa (525 ksi) for the backfill during initial undercut mining and also indicating the onset of strain hardening behavior in the paste fill during a fifth undercut advance. The instruments are currently being monitored every two hours by data acquisition systems that are linked through the mine's communications systems to a corporate web site and are thus providing the mine staff and NIOSH researchers with reliable, timely information regarding the geomechanical behavior and stability of the backfill.

9:45 am

Stability Analysis of Backfill and Underground Pressure Control in the Large-Scale Deep Mining

F. Wenlu, China ENFI Engineering Corporation, Beijing, China

For the reason that Anhui Shapinggou Molybdenum mine with large-scale deep mining appears obvious underground pressure, the arch facade sequence mining and subsequent backfilling are designed for controlling the frequent underground movement. The numerical analyses of arch facade mining sequence and conventional upward horizontal slice mining sequence are carried out respectively, and static calculation and dynamic calculation are carried out for the stability of backfill. The analytical results show that the maximum principal stress distribution is uniform in the arch facade mining, and the arch facade mining has smaller degree of stress concentration and less plastic area than those of conventional sequence mining. Because of a better supporting role arising from the vaulting, the surface subsidence displacement caused by arch facade mining is smaller than that caused by conventional sequence mining. The operating range of blasting vibration influences the variation of plastic zone and displacement for backfill. When the blasting dynamic loading is applied near the backfill, the distribution area of backfill plastic zone is expanded obviously. If the curing time of backfill is insufficient, the backfill is prone to collapse.

10:05 am

Practical Geotechnical Design in Backfill at the Turquoise Ridge Mine, Nevada

C. Barnard and L. Sandbak, TRJV

Cemented rock fill (CRF) commonly referred to as backfill has been utilized as the main support in the underhand cut and fill (UCAF) mining method at the Turquoise Ridge Mine (TRJV). The design is based on flexural instability utilizing fixed beam analysis, originally developed by Mitchell and Roettner (1989) and later Stone (1993). The methodology has been utilized to increase our average undercut width from 20 to 30 feet. The opportunity also exists to lower mine costs by adjusting the cement content without jeopardizing necessary mine design safety factors. Numerical monitoring and instrumentation has also substantiated minimal pressures and movement from current designs, and could facilitate even wider undercut widths or expanded mining methods in the future.

10:25 am

Reliability Analysis of Mine Backfill Exposures

M. Helinski and D. Merrikin, Outotec Pty Ltd , South East Asia Pacific

The largest operating cost associated with most cemented mine backfill systems is binder. Binder dosage is typically based on the results of the quality control strength testing, a suitable model for estimating the strength requirements and a Factor of Safety (FoS). In the author's experience factor of safety (FoS) (or equivalent) can range from 1.2 to 2.0, often with no rational basis for selection. At typical mine backfill operations this range may equate to a 1-3M USD difference in annual binder costs. Consequently, selection of a suitable FoS, which properly reflects the material and model uncertainty, is considered necessary. This paper presents the results of analysis that was undertaken for the purpose of providing guidance relating to a suitable FoS for cemented mine backfill design. Work presented in this paper utilizes Monte Carlo simulations of a typical mine backfill vertical exposures to derive a rational approach for using variable quality control strength data (either plant sampling or in situ measurements) for the design of fill exposures.In addition to providing a rational approach to addressing material uncertainty, this paper also provides recommendations relating to the selection of appropriate model uncertainty safety factors. While limited in scope the presented results provide useful guidance for the selection of appropriate model uncertainty safety factors when applying simplified analytical solutions, compared with more rigorous numerical methods.

10:45 am
Numerical Modeling of the Evolution of Pore Water Pressure within Cemented Paste Backfill Structure
M. Fall, and L. Cui, University of Ottawa, Ottawa, ON, Canada

The pore water pressure (PWP) has a significant effect on effective stress and strength development in cemented paste backfill (CPB) structures. Moreover, the PWP has a considerable impact on stability and design of barricades. Hence, it has paramount and practical importance for stability analysis as well as the cost-effective design of CPB structures and barricades. In this study, a multiphysics model is developed and successfully validated against laboratory and field data to assess and predict the development and evolution of PWP within CPB mass. A series of engineering issues are then examined with the model to investigate the PWP in field CPB mass with respect to the changes in the mixture recipe, as well as the backfilling, surrounding rock and curing conditions. The obtained results provide in-depth insight into the PWP evolution in CPB.

MONDAY, FEBRUARY 20, 2017
AFTERNOON

2:00 pm Room 603
Laboratory Testing/Research I
Chair: *Russ Evans, Goldcorp*

2:00 pm
Introductions

2:05 pm
Industrial Practice on Optimizing Tailings Composition Combined with Ore Concentration Processes
L. Guo, X. Yang, B. Yu, W. Xu, C. Shi and X. Peng, Beijing General Research Institute of Mining and Metallurgy, Beijing, China

Cemented paste backfill (CPB) is increasingly applied in underground mines world-wide and has a broad prospect considering its benefits in environmental protection and ground control. During the paste production, a well-graded aggregate is critical for the achievement of CPB. Mine tailings from the outcome of ore-dressing plant are commonly used as the fill aggregate. However, it is difficult to obtain an ideal particle size distribution for the mine tailings which are roughly mixed with final residuum in ore concentration processes. In this study, a novel industrial method is proposed to select fill aggregates from different parts of ore-dressing processes. With combined design of concentration plant and backfill plant, the tailings with desired particle sizes and proportions during the mineral processing are chosen to produce CPB without disturbing the regular ore concentration. The problem of passively accepting final tailings from ore-dressing plant has been improved.

2:25 pm

Éléonore Paste Backfill Composition

S. Girard, P. Lajoie, and P. Germain, Eleonore Gold Mine, Goldcorp Inc., Canada

Paste backfill and uncemented rockfill are used at the Éléonore gold mine to allow pillarless recovery of the narrow gold veins. A major constraint of the Eleonore operation is to store the sulphide tailings underground. Maximizing uncemented rockfill underground is an important economic factor. A good balance of paste backfill and uncemented rockfill is critical to allow the mill to discharge the sulphide material without compromising paste quality and the continuous mill operation. This study is part of an ongoing internal research program that aims to find an economical mix design with desired fresh and hardened properties at high sulphide content. The effects of the different mix parameters were evaluated independently using the compressive strength at different curing times. All of the mixes were batched at the same consistency. This paper covers the mix design philosophies and challenges encountered during full-scale implementation tests along with innovative techniques used at the Eleonore paste backfill plant.

2:45 pm

Enhanced Flow Ability and Mechanical Characteristics of Cemented Paste Backfill with a Chemical Admixture

S. Haruna and M. Fall, University of Ottawa, Ottawa, Canada

Cemented paste backfill (CPB) with excellent flow ability and a high rate of early strength gain achieved in an economical manner is a key target in the backfill technology. This paper presents the results of an experimental investigation of the effect of a novel chemical admixture (Master Glenium 7500) on the rheological properties (yield stress, viscosity) and mechanical properties of CPB. The yield stress and viscosity of CPB samples containing 0%, 0.05%, 0.125% and 0.25% admixture were tested up to 4 hours. Unconfined compressive strengths (UCS) of the samples were also determined after 1, 3, 7 and 28 days. The results obtained show that the admixture significantly reduces the viscosity and the yield stress of CPB. The admixture also proved to be important on strength development. At the initial stage, up to 3 days curing period, samples with admixture show lower UCS but become stronger than the treated samples after 7 days. This shows that this admixture can significantly improve the rheological properties, strength and strength gain rate of CPB. The findings of this study will therefore help to prepare CPB with enhanced performance properties.

3:05 pm

Engineering Backfill Fiber as an Environmental Solution to Cost-reduce and Improve Paste Backfill

B. Ting, Gopomo Inc.; K. Yoo, and H. Yoo, PT. Ecofiber; K. Ruptash, and B. Fabian, Nahanni Construction

This paper discusses the paste design and the experimental results of using an environmentally benign additive known as engineering backfill fiber (EBF), which can potentially and significantly reduce of the cost of paste backfill. It was found that paste with EBF produced less bleed water and developed higher strength. The improved high early strength allowed a more flexible mining and backfill schedule. The use of EBF may also be used for managing the risk of liquefaction and improve safety. The tailings, binder, and water used in this series of experiments were collected in a real world mining process.

3:25 pm
Feasibility Study of Overburden Material for Hydraulic Stowing in Mines
I. Muthreja, A. Ghare, R. Yerpude, L. Dhote, Visvesvaraya National Institute of Technology

The results discussed in this paper highlighted a Feasibility study of overburden material (OBM) from mines as stowing/backfill material. The study refers significant physical parameters like particle size, dry density, porosity, permeability etc. The flow characteristic i.e. pressure gradient change for slurry transport of OBM) for 37.5 mm circular pipe have been experimentally evaluated. The linear expressions related with change in pressure gradient have been presented using multiple regressions of data. Water percolation characteristic after placement of slurry also have been evaluated experimentally. The commonly used stowing material; sand is taken for the comparative analysis with overburden material.

3:45 pm
Research on Automatic Control Filling System
K. Zhan, L. Yu and D. Zhang; Beijing General Research Institute of Mining and Metallurgy, Beijing, China
With the development of information technology, digital mines has become a development goal of the mining enterprises in recent years. The equipment intelligent, automation production, management information mining mode of production is being extended gradually, the digital management system of filling has become an important project of digital mined development. This paper studies the remote automatic filling process control, material concentration and flow rate of the real-time monitoring technology, to develop a suitable metal mines filled automatic control system. The system is applied in a copper mine enterprises. The test results show that the system realizes the production equipment and process for remote status monitoring and management, optimize the number of staff, reduce labor intensity and improve packing efficiency, to achieve a continuous and stable mine production.

TUESDAY, FEBRUARY 21, 2017
MORNING

9:00 am **Room 603**
Laboratory Testing/Research II
***Chair**: Ferri Hassini, McGill University*

9:00 am
Introductions

9:05 am

The Short-Processing Tailing-Storage-Free Filtration Backfilling Method

X. Liu, Energy and Engineering Safety School of Human University of Science and Technology, Xiangtan City, China

In order to meet the need of efficient backfills in some low grade and hard-to-recover mines, a new backfilling method named short-processing tailing-storage-free filtration backfilling method was invented by studying on the quantity and concentration control of filtrated slurry, as well as optimizing of mine operating flowchart and cyclone clusters. No tailing storage is required for this system; as a result, tailings can be transported to cyclone clusters directly. Generally, the concentration and production rate of the downstream inside the cluster is between 68% to 72% and 69% to 72% respectively. This downstream then flow directly down to the continuous mixers for the mixing with cement, and ultimately, was filled into the voids through underground reticulation systems and boreholes. The installation time for this system has been reduced to 4 months, while the capital investment and operating cost are also reduced by 70% and 20% respectively. The strength of the filling body, with ratio of cement to sand 1:4, can reach up to 3.2Mpa in 28 days. Therefore, this system can be effectively integrated with the overall mining sequence, balance the mineral extraction rate and processing rate safely, hence to improve the profitability of the mine.

9:25 am

The Technology of 3d Laser Scanning Applied to Cavity Backfill Governance

Z. Kai, C. Kai and Z. Da, Beijing General Research Institute of Mining and Metallurgy, Beijing, China

There are a large number of different sizes and shapes cavities when mines use the openstope method to mine, and these cavities will have influence on mine condition, then cause serious geological hazard such as the roof fall-rib spalling-closure deformation of the cavity – even surface collapsing, all of geological hazard can threaten mine safety. Using backfill method to deal with dangerous cavities is the best efficient method which will prevent wholesale ground pressure activity. However, it is difficult to obtain cavity shape and calculate backfill amount if mine uses backfill method to deal with dangerous cavities. To solve this problem, this paper introduces the 3D laser scanner for mine which is developed by Beijing General Research Institute of Mining and Metallurgy to scan cavity before mine backfill and probe the whole or part shape and real time condition of cavities, then obtain whole-comprehensive-continuous point cloud data. point cloud data will be converted into line model-entity model-profile data, these data will provide intuitive information to constitute backfill process for cavity and calculate backfill amount precisely to solve the problem which is difficult to check backfill amount of cavity.

9:45 am

Polymer Wear Materials – The Right Product for Different Applications

P. McDonald, Iracore International, LLC.

Wear is the result of material loss due to impingement, impact, scuffing, and the sliding of particles across the material surface. Add to that the many other variables which affect the wear rates such as pressure, temperature, velocity, and particle size just to name a few. With that being said wear is very application specific. There are a few standard tests such as the National Bureau of Standards (NBS), DIN and the Taber Abrasion that provide guidance, but often specific field tests must be conducted to determine the best material. This presentation describes the relationship between lab data and field results with various types of cast polyurethane systems. In the end, experience in various operating environments is often needed in order to select the proper polyurethane system for the specific wear service.

10:05 am

Cemented Aggregate Fill Test Work

J. Wickens and B. Snyman, Paterson & Cooke Consulting Engineers (Pty) Ltd, South Africa

There are many forms of backfill that can be considered for a specific mine application and the mine plan, layout and mining method are all key criteria required to develop the appropriate backfill properties. In some instances, a high strength fill may be required for large bulk open stopes and aggregate fill may be the best solution. However, generating suitable aggregate can present logistical challenges and so is often considered an expensive option, but in cases where development waste is readily available, a cemented aggregate fill (CAF) may be an appropriate and cost effective solution. Open stope mining creates large voids and properly designed backfill is used to ensure regional stability as well as to maximize the extraction ratio. CAF is broadly defined as a rock fill that can be modified to suite the mining requirements by optimizing the particle size distribution through a combination of screening, inclusion of tailings or crushing of the waste rock, and adding binder such as cement. The requirements to conduct UCS test work on CAF presents unique challenges and a specially designed and constructed 50 tonne load frame was developed for this test work. This paper presents results from a series of laboratory scale tests on CAF to determine the effect of particle size distribution on the unconfined compressive strength (UCS) so as to optimize the binder content of a CAF backfill product.

10:25 am

Back Fill Optimization and Innovation – Red Lake Gold Mine's Success Story

N. Hmidi, R. Evans, D. MacDonald, K. Cook and K. Tietz, Goldcorp Canada

Backfill production can be challenging in a mining environment in which multiple mining methods are in use (longhole, overhand & underhand cut and fill). It becomes even more complex when there are multiple headframes, two processing facilities, and associated pastefilling facilities, and where many small, high grade stopes take priority over all others. The complexity of this type of operation in a mine that is mature and where the stoping areas are widely spaced and deep, can present many obstacles to maintaining the ideal inventory of stopes ready to fill and the reticulation to support. Numerous associated obstacles over time led to a backlog of 80,000 tons of unfilled stopes. Such a deficit is very difficult to overcome when the pressure to meet targeted ounce production can lead to short term decisions which eventually create long term pain. This paper describes the actions that were taken to completely overhaul the backfill process, eliminate the backlog and implement a sustainable system that will ensure the future success of the mine. Through innovative improvements, via a structured team approach, with a focus on design flexibility, improved processes, optimization, and a simple mantra “do every task as soon as you can do it,” significant step changes in backfill management were achieved. Changes to organizational structure, planning, scheduling, and coordination, along with optimized preparation, transportation, and distribution, were achieved through the introduction of a philosophy where through team work, collective awareness, understanding, and ownership successful outcomes are achievable.

10:45 am

Extending Paste Pumping Envelopes at Minera San Rafael’s Escobal Mine through the Use of Admixturesand Pressure Spike Dampening

M. McGuinness and R. Brown, Paterson & Cooke Canada Inc. and C. Barich, Tahoe Resources Inc.

Expanding the existing pastefill distribution system to the East Zone of Minera San Rafael’s Escobal Mine posed a challenge due to long pumping distances and high discharge elevations. Several options were considered for delivering pastefill to the new area which included procuring a replacement higher pressure surface pump, installing an underground booster pump station and increasing the efficiency of existing site infrastructure with a pressure damper and admixtures. Hydraulic modelling inputs were refined after a series of field trials and the final decision was made to use admixtures and to install a pressure dampener to reduce peak pressure spikes and increase the average operating pressures with existing site infrastructure. This paper outlines the steps taken to reach this decision including testing, modeling and an economic evaluation. It presents how the pressure dampener and admixtures are used to extend pumping distances while maintaining targeted paste quality.

TUESDAY, FEBRUARY 21, 2017

AFTERNOON

2:00 pm Room 603

Backfill Reticulation, Barricades, Instrumentation

Chair: *Tony Grice, AMC Consultants*

2pm

Introductions

2:05 pm

Use of Cemented Paste Backfill Boreholes for Concrete and Shotcrete Delivery

P. Primeau and B. Mandl, Golder Associates Ltd., Sudbury, Ontario, Canada and T. Guse and K. Bullock,Glencore's Sudbury Integrated Nickel Operations, Sudbury, Ontario, Canada

Deeper underground mining is becoming more prevalent throughout the world. With this comes the fact that the installation of infrastructure to deliver bulk materials in support of mining, can add significantly to the overall cost of a project. To this end, the multi-purposing of required infrastructure can lead to significant cost savings during a mine's development, and operation. The use of cemented paste backfill dipped boreholes for delivery of concrete and shotcrete underground is one possible way to bring about economical and efficiency benefits to a project. This paper presents some of the design and technical consideration that went into such an evaluation as part of Feasibility studies undertaken by Glencore's Sudbury Integrated Nickel Operations (Sudbury INO) for the Onaping Depth (OD) Project.

2:25 pm

Numerical Analyses of the Stress Distribution in Backfilled Stopes Considering Interfaces Between the Backfill and Rock Walls

G. Liu, Beijing General Research Institute of Mining and Metallurgy, Beijing, China; L Li École Polytechnique de Montréal, Montreal, Quebec, Canada; X. Yang and L. Guo Beijing General Research Institute of Mining and Metallurgy, Beijing, China

Minefill is widely used in underground mines around the world, mainly to improve ground stability, reduce ore dilution and maximize ore recovery rate. To successfully apply backfill, it is a critical issue to evaluate the stresses in backfilled stopes. Previous published works have shown that numerical modelling is an effective mean to accomplish this task. However, most of the numerical models did not consider interfaces between the backfill and rock walls. The influence of the mechanical properties of the interfaces was seldom systematically investigated on the stresses in backfilled stopes. In this study, the stress distribution in backfilled stopes is analyzed using FLAC3D after taking into account interface elements. The influence of the planar and nonplanar interfaces, as well as the shear strength and roughness on the stresses in backfilled stopes will be presented and discussed.

2:45 pm

In Situ Instrumentation of a Cemented Paste Backfilled Stope at George Fisher Mine

R. Veenstra, George Fisher and Lady Loretta Mines, Glencore, Australia

George Fisher Mine (GFM) is currently in the process of optimizing its pour and backfill barricade designs. Part of this process involves the installation of in situ and barricade instrumentation to monitor the loads being placed on the barricade and the response of the barricade to these loads. This paper presents the first installation at GFM, which involved total earth pressure cells and piezometers installed immediately upstream of the CPB barricade wall, and ShapeAccelArray instruments installed on the downstream side of the barricade. The results obtained from showed that the pressures experienced by the barricade were lower than anticipated and significantly lower than the GFM's current design barricade design stress. The isotropic stress period of approximately 5 hours was also shorter than expected. The instrumentation also showed signs of possible thermal expansion. Overall, this instrumentation was a positive first step in helping characterizing GFM's in situ backfill behavior, with more comprehensive installations being planned in the future.

3:05 pm

In Situ Backfill Monitoring – Lessons Learned and a New Case Study

B. Thompson and W. Bawden , Mine Design Engineering, Ontario, Canada; B. Brzeczkar, Barrick Gold Corporation, Toronto, Ontario, Canada and M. Grabinsky, The University of Toronto, Ontario, Canada

In the 10 years since Grabinsky and Bawden (2007) published initial data from an extensive campaign of in-situ measurements of backfilling stopes, a better understanding of how in-situ backfill behaves, and how operations can use this information to safely improve the efficiency of their backfilling operation has developed. In part, this is due to an ever increasing catalog of published field data. In order to continue this trend, we present a detailed review of the instrumentation, and installation techniques that have worked best as the initially research focused work has been applied on a consulting basis. A recent case study from Barrick Gold Corporation's Williams mine is presented, where relatively low (63 kPa) barricade pressures were measured during a trial to investigate the suitability of continuously backfilling. Importantly, the transition from hydrostatic loading occurred within several hours, which indicates the transition from a fluid backfill to soil like material was relatively rapid, and likely is a key factor in the relatively low barricade pressures. This data indicates that subject to appropriate QA/QC, including real-time monitoring of barricade pressures, reduced stope cycle times through more efficient backfilling may be possible. Further, barricade displacement has been measured and demonstrated to correlate with barricade pressures. The peak displacement was 0.4 mm. This data will be useful in a site specific barricade strength calibration project.

3:25 pm

The Garpenberg Paste Backfill Reticulation System – A Case Study

D. Granlund and S. Wilson, Paterson & Cooke UK Ltd, UK; C. Eriksson and M. Nordlund, Boliden, Sweden

The Garpenberg Mine in Sweden is owned and operated by Boliden, producing lead and zinc concentrate. The mine has been operated by Boliden since 1953, and has recently (2014) undertaken a major operational and production upgrade with the construction of a new processing plant operating at 2.5 Mtpa of ore production. The revitalisation being driven primarily by the discovery of increased mineral reserves and resources offering a production life past 2030. A backfill system has been operating at the mine since 2007, producing a paste backfill from de-slimed mill tailings. Between 2015 and 2016 Boliden, with support from Paterson & Cooke's Backfill Group undertook a program of work to improve the operational performance of the system, focusing on increasing system availability and throughput, as well as enabling reticulation into the new Kvanberget ore body. This paper is presented as a case study to describe an approach to overcome commonly encountered paste reticulation system problems, notably expansion to new mining areas, system availability and excessive system wear. Specifically, the case study describes how, through the introduction of diversion valving, level loops and hydraulic modelling, the system availability has been increased. The hydraulic modelling including completion of a rheological loop testing to better quantify the paste characteristics so that, through hydraulic modelling the consistency of the backfill could be adapted to ensure full flow operating conditions, accounting for inclusion of the new level loops.

3:45 pm

A Better Understanding of the Tailings Properties Can Potentially Lead to Improved Backfill Economics

T. Skocir and I. Ahmed, Golder Associates Ltd., Mississauga, Ontario, Canada; G. Barr, Twin Metals Minnesota LLC, St. Paul, Minnesota

As development projects and operating mines drive for efficiencies, both capital and operating cost are often scrutinized. The selection of technically viable and cost effective backfill is an important task for many underground mines. This paper presents the findings of a study for the Twin Metals Minnesota Project that looked at the results of combining a tailings that readily dewaters, with a slow set binder, such as slag cement. The resulting proposed backfill plant design takes on the simplicity reminiscent of a standard hydraulic fill plant yet maintains the performance and operational benefits of a typical paste fill plant. In this case, dewatered tailings from a high rate thickener can be combined with slag cement to achieve unconfined compressive strengths that are similar to paste.

WEDNESDAY, FEBRUARY 22, 2017

MORNING

9:00 am **Room 603**

Equipment, Case Studies, New Technology I

***Chair**: Robert Cooke, Paterson Cooke*

9:00 am

Introductions

9:05 am

The Benefits of Incorporating Admixtures into Mine Paste Backfill

F. Erismann, Sika Tunneling and Mining, Switzerland; S. O'Hara, Sika Tunneling and Mining, Canada; C. Kurz, Sika Technology, Switzerland; M. Hansson, Sika Tunneling and Mining, Sweden

The benefits of incorporating chemical admixtures into mine paste fill designs are numerous and cost effective, especially when incorporating metrics such as energy- and cement consumption, reduced dewatering costs, reduced downtime and pipe blockages as well as reduced plant maintenance costs into the equation. The addition of admixtures is a tool to optimize the backfill product in order to have a direct feedback on the backfill quality and numerous operating cost centres. Using admixtures provides the paste fill engineer with a tool to adjust and modify many variables of the paste mix. The following variables can be modified in order to obtain a cost performing backfill paste: enhanced rheological behaviour (better thixotropic profile, improved slump, better pumpeability), reduced water content, reduced cement content or change of cement type, increased solid content, improved compressive strength and improved cure time. An adjustment to any of the mix design variables can result in significant improvements of the paste cost-performance and reduction in overall operational expenses. Test results have proven that the addition of a single admixture at relatively low dosage of 1% to 3% by weight of cement can have powerful effects in modifying the parameters listed above. A prerequisite for good results is a good understanding about the mineralogy and granulometry of the ore host and therefore the source of the tailing material which leads to a customized adjustment of the used admixture in any given paste backfill operation. This paper outlines results from different mine backfill pastes and how to come up with the right admixture choice.

9:25 am

Backfill Design under Challenging Conditions

W. Hohl, University of Leoben, Leoben, Austria; G. Daxner, G. Hofer and M. Lanthaler, Salinen Austria AG, Austria

Salt mining in Austria commences today for more than 5000 years. Past mining activities have left remnant stopes which could pose a risk for mine stability. A research project was initiated to develop a backfill design methodology for the special conditions encountered in the salt mines. Special focus was laid on the determination of suitable rock mass parameters since the host rock exhibits a time-dependent behaviour. It was possible to establish parameters for the rock mass and the backfill using a large 3D-model comprising the complex mine geometry, high precision levelling measurement data and stress measurement data. The filling of these remnant stopes was completed without incidents based on the findings of the presented study.

10:05 am

The Future of Backfill in Underground Coal Mines – Underground Placement of Fill Material Based on Fly Ash and Coal Processing Waste

J. Palarski Silesian University of Technology, Gliwce, Poland; A. Zajac, EDF Ekoserwis Sp. z o.o, Gliwice, Poland

Polish underground coal mines successfully adopt new method of filling of gob area in logwall. Currently, due to cost reasons, most of conventional backfill operations have been stopped, however many mines are equipped with the hydraulic backfill infrastructure. This infrastructure, mainly pipelines networks, can be easily applied for transportation of fine-grained mixtures used for filling of gobs. Placement of ashes, slag and processing waste in mined areas at Silesian coal mines began in XIX centuries. Such practices have been employed at both active and abandoned coal mines. The current filling technology of gob area in longwall operation allows to avoid surface subsidence, utilize fine waste and saline mine waters, improve stability of rock mass and reduce some of the ventilation problems such as loss of air into the gob in the headgate area (the loss can reduce the air available to ventilate the longwall face), gas emission and spontaneous coal combustion. The purpose of this paper is to present the current fill operation, the results obtained by applying a new method in longwall mining and a number of problems related to environmental and safety issues. Physical properties and requirements for fill materials and mixtures will be discussed.

10:25 am

Northam Platinum Zondereinde Mine – UG2 as Backfill Product

J. Snyman, Paterson & Cooke Consulting Engineers (Pty) Ltd, South Africa; C. van Jaarsveld and D. Gonsalves, Northam Platinum Ltd – Zondereinde, South Africa

The Northam Platinum Zondereinde mine is performing multi-reef mining by exploiting two types of platinum bearing reef, known as the Merensky and UG2 reefs, each with differing ore characteristics and resulting tailings properties. The mine has been using uncemented hydraulic backfill for primary as well as regional support since the start of the mining operations in 1993. Historically, the backfill material comprised of classified Merensky and, to a lesser extent, development waste tailings. Northam Platinum Zondereinde mine is now investigating the use of UG2 tailings as backfill material should the availability of Merensky tailings not meet the required future volumetric placement demands. The suitability of UG2 tailings as backfill material was investigated through benchtop tests, followed by a full scale test paddock on surface. The test paddock was equipped with total earth pressure cells and piezometers to assess the stress build up in the backfill during and after placement as well as the drainage potential of the material in the paddock. In addition, different geotextiles were trialled to optimise the volume of drainage water, while limiting the amount of solids released from the trial paddock. During the field trials, slumping events were witnessed inside the test paddock which resulted in increased loading conditions on the fill fence. This paper presents the backfill system, test setup and results from the field trials as well as a discussion, and probable causes, of the slumping events that were witnessed during the field trials.

10:45 am

Paste for In-Pit Tailings Disposal Applications

I. Karajeh, Golder Associates Ltd., Mississauga, Ontario, Canada

Many mines start as an open pit operation and advance into underground developments. In some cases, paste is selected as the backfill method of choice. For these operations the potential to place tailings in the existing inactive open pit can be beneficial from an environmental and cost perspective. The operation can delay or eliminate the need to permit a new tailings storage facility. One of the key challenges with in-pit deposition in general is the management of water. A highly dewatered tailings such as paste can be the solution, and to those operations that have a paste backfill plant, the advantages are apparent. This paper discusses the engineering considerations for an in-pit tailings disposal design with a particular focus on the advantages of delivering a paste consistency material.

11:05 am

Hitchhikers Guide to Human Error

C. Pitzer, SAFEmap International Inc., Vancouver, BC, Canada

The safety science is trapped in the management concept that ‘what gets measured gets done’, and the belief that incidents rates are actually validly and reliably measuring safety performance. We give incentives based on false data, and we spend huge resources on misconceptions, achieving little more than looking very busy. The more recent focus on the art of leadership, as against the ‘science of management’, has brought a deep and different understanding of people in the work place - that human motivation is a complex but powerful force that can be harnessed. The approach argues that if people are given authority and trust, they will excel. If people understand and believe in the true purpose of safety, they will sign up. When it comes to promoting job-site safety, how much messaging is too much? How much risk-identification and management is too much? Is there such a thing as too many safety rules and guidelines? While most people argue that job-site safety can never be promoted enough, one safety-industry researcher suggests otherwise. Corrie Pitzer argues that many organizations suffer from delusions when they think about safety. He suggests that by driving risk-identification and risk-management strategies, as well as promoting “unrealistic” goals such as zero accidents, safety managers unwittingly create organization-wide delusions that actually cause more harm than good. Because Pitzer uses strong language to describe his approach, he's often characterized as not caring about ordinary men and women who risk injury or death in dangerous workplace situations. Nothing could be further from the truth. Rather, Pitzer and his team study traditional approaches to safety through unusual means, and the conclusions they draw are based on data gathered through years of careful study. Analysis shows, quite clearly, that some of the modern approaches to workplace safety have fostered more harm than good. Although the approaches themselves are not without merit—it's reasonable to want to control risk, and it's laudable to want to reduce accident rates—as a society, we have arrived at a point where organizations drive such approaches harder than ever, to the point where these notions are being followed slavishly and without any regard to their broader consequences. According to the author, accidents are largely not preventable. As organizations are operating increasingly closer to 'zero', accidents are increasingly random events, caused by chance circumstances and inherent risks that randomly interact. Moreover, by creating illusions of compliance and consistency, where workers are encouraged to follow rules and procedures unquestioningly and without relying on their own common sense and instincts, safety systems can actually promote disaster. The author describes seven deadly delusions from which organizations suffer.

WEDNESDAY, FEBRUARY 22, 2017

AFTERNOON

2:00 pm Room 603

Equipment, Case Studies, New Technology II

***Chair**: Betty Lin, Hatch*

2:00 pm

Introductions

2:05 pm

Portable, Modular and Custom Built Backfill Plants – Choosing the Right Plant

C. Lee, Golder Associates Ltd., Sudbury, Ontario, Canada; R. Brown, Paterson & Cooke, Sudbury, Ontario, Canada

There are many ways to design and construct a backfill plant for cemented hydraulic fill (CHF), cemented rock or aggregate fill (CRF/CAF) or cemented paste fill (CPF). Backfill plants can be simple, mobile plants that require little in the way of permanent fixed infrastructure. Prefabricated modular plants are also an option and can allow clients to reduce construction costs by performing the majority of the construction and assembly work in a fabrication shop rather than on site. Lastly, custom plants, constructed at the minesite can be designed around competitively-bid equipment, with the optimum layout for operation and maintenance without any limitations due to transportation size restrictions or equipment dimensions. The three backfill plant options listed previously (mobile, modular and custom), and a variety of hybrid options that mix the characteristics of the three, are not always well understood and the risks, advantages and disadvantages of the various options can be overlooked when selecting a plant option that is right for a particular site. This paper seeks to identify the various options available for backfill plant design and discusses the pros and cons of the options. The intent is that this paper will help mine operators understand their options better, match their approach with their environment, and avoid unintended consequences when selecting a backfill plant type.

2:25 pm

Technology and Application of Mechanized Longwall Face Using Roadway Driving with Backfill The Study of Roadway Backfill Coal Mining Technology with Water-preserved in Western Eco-environment Frangible Area

Z. Jixiong, S. Qiang, Z. Qiang, Z. Nan and Y. Hao, China University of Mining & Technology, Beijing, China

In China's western eco-environment frangible area, the traditional fully mechanized caving or room mining method is facing coal pillar instability, mine earthquake, large-area roof subsidence in the goaf, surface subsidence, water and soil loss, vegetation deterioration and other environmental problems. To solve the aforementioned problems and improve coal recovery, the roadway backfill coal mining (RBCM) technology with water-preserved was proposed as a solution and its technical principle, key equipment, roadway layout and backfill mining process were presented in detail in this paper. The mechanical properties of backfilling materials with different ratio of aeolian sand, fly ash and cement are studied in laboratory for a optimum ratio for local coal mines. moreover, a two-dimensional physical simulation model is established to analyze the characteristics of overlying strata movement and effect of water-preserved. Field application results shows that this technology can effectively control the overlying strata movement and improve the recovery rate of coal resources, achieving the coordinated development of the western mining area resources exploitation and environmental protection purposes.

2:45 pm

Report on Tailings Dewatering with High Performance Disc Filters

J. Hahn and A. Egger, BOKELA GmbH, Germany

The treatment of tailings and paste from ore processing filtration and dewatering has gained more and more significance in the recent years. The recovery of water from the process is an important target with respect to both economic and environmental aspects because water is a valuable resource. The dewatering of tailings allows dry-stacking which is environmentally more acceptable, safer, and cheaper and especially with mine backfill it allows to reduce the amount of cement to be added which may save millions of dollars per year. The most common dewatering technologies for the filtration of tailings and paste from ore processing are filter presses, belt filters and rotary vacuum disc filters. Among these the vacuum disc filter is the most economical technology in most applications – both in CAPEX and OPEX – especially, when high performance disc filters of modern filter design are used. The Boozer disc filter is a modern high performance vacuum disc filter which has set the pattern in a multitude of applications. In the recent years this filter type has established itself in many applications of tailings dewatering initiated by a first reference application which started operation in 2010. In this application the use of two Boozer disc filters allowed to reduce the input of cement by about 60%. The reasons for the successful operation of this disc filter in tailings dewatering are: the high throughput and dewatering performance, the excellent operational reliability even in case of varying feed conditions, the simple and robust design, the ease of maintenance and last but not least the small footprint. The paper reports on operation experience and operation results of tailings dewatering with the Boozer disc filter from 3 different plants with 3 different tailings. In one of these plants a Boozer disc filter is operated in the Andes in more than 4,000 meter above sea level.

3:05 pm

Pulsation Free Hydraulically Driven Piston Pump

E. Vlot, Weir Minerals Netherland b.v.

The mining industry has recognized the advantages of high density backfill or ‘paste’, which is typically pumped with a hydraulically driven piston pump. Due to the discontinuous flow of this type of pump, pressure pulsations can occur in the discharge line. Pressure pulsations are an undesired phenomenon in pumping installations for a number of reasons, such as damage to the pumping system, including piping and supports, disturbing noise levels and even safety risks for operators and maintenance personnel. This paper describes an advanced system on the GEHO® piston pumps, which will prevent pulsations from occurring, rather than merely reducing the already existing pulsations.

3:25 pm

Pulsation from Positive Displacement Pumps

P. Mainville, Outotec

Paste backfill reticulation systems are often designed around steady state friction losses and pressure effects from elevation changes. Most positive displacement pumps do not operate at steady state. The pressure pulse, which results from each pump stroke, is a combination of acceleration forces and friction losses. This paper investigates the magnitude of the acceleration forces, explores the circumstances where these forces could become a fatal design flaw, and possible alternatives which reduce or remove the pulses.

3:45 pm

Tailings Backfill for 2Optimizing Pit Lake Water Quality

M. Novotny, DHI Water & Environment, Inc., Lakewood, CO; B. Johnson, Hydrogeologica, Inc., Golden, CO; D. Castendyk, Hatch Consultants, Inc., Lakewood, Colorado

A prefeasibility-level mine closure study of the Metates open pit, gold and silver project in Mexico was recently completed that involved optimized partial backfill of tailings into the pit. The study considered several treatment options to improve pit lake water quality including mixing of lime with the upper horizons of tailings backfill in order to neutralize acidity in the tailings pore water and pit lake. Models of groundwater flow, water balance and pit lake geochemistry were used to predict and optimize the pit lake water quality. Results highlighted trade-offs between the treatment options and were used to manage the overall project cost and risk.

4:05 pm

Utilizing Paste Diverter Valves to Optimize Paste Backfill Operations

S. Sargent and M. Prince, Victaulic

Underground mines use intricate piping networks, known as paste backfill systems to fill stopes after extracting materials for processing. These piping networks require extensive manual labor to operate and maintain a functional system, as these systems operate under extremely rigorous conditions. Diverting paste fill from one stope to another requires removal and reinstallation of the pipe to redirect the flow of the line. This process is laborious, time consuming, and requires extensive planning to ensure safer operations. New innovations and products are now making these manual processes a thing of the past, resulting in increased backfill reticulation, job site efficiency, and safety. This paper evaluates a new system that uses a diverter valve, as opposed to manual changeover, to reduce downtime, eliminate safety hazards, and increase processing throughout.

TECHNICAL PROGRAM

MONDAY, FEBRUARY 20

AFTERNOON

1:30 pm **Room 113**

Dreyer Lecture

Lecturer: *Ron Parratt*

Right Time, Right Place, Right People

MONDAY, FEBRUARY 20

AFTERNOON

2:00 pm **Room 210**

Accessing Capital in Mining Today: Managing Through the Cycle

Chair: *T. Alch, Executive Director of New York Section of SME and Managing Partner of TAA Advisory, LLC.*

Join our experts who will speak about key issues and latest trends and answer your questions about raising capital in mining today. It is a challenging environment; as metals' prices go down and up, so do investors' and lenders' interest and valuations. If you are in the exploration and mining business, an investor or owner, you will want to hear our speakers discuss: What can you do to help raise capital? Is the capital available suitable? How do technical, non-technical, legal, and societal issues and risks impact raising capital? What should you know about debt, equity, or other sources of capital such as private equity, hedge funds, royalty, and streaming companies? If in distress, what can you do? Is M&A, consolidation and or restructuring the best option? Join us to hear our Speakers discuss these issues and latest trends, and get your questions answered.

2:00 pm
Introduction by Panel Chair
Tim Alch, Executive Director of NY SME and Managing Partner of TAA Advisory, LLC

2:05 pm
A Banker's Perspective of Funding Mining Projects
Alain Halimi, Head, Metals & Mining, Americas at Commonwealth Bank of Australia

Mr. Halimi will discuss trends about funding of mining projects, key bankability issues when lending; impact of and importance of confidence levels of geologic, feasibility studies; the quality of deposits and arrangement between off-takers and miners; whether hedging is advisable; factors that influence the level of equity and debt in structuring a mining company; and how to figure unknowns in to financing structures.

2:25 pm
The Role of the Independent Engineer in Project Finance
Richard Lambert, P.E., P.Eng., Principal Mining Engineer, Executive Vice President and Chief Operating Officer, RPA

Mr. Lambert will cover the assessment of technical and economic risk and lender's tolerance for risk.

2:45 pm
Integrated Business Planning – an Enabler for Raising Capital
Ajay Kumar, Manager, KPMG LLP

Integrated Business Planning (IBP) helps achieve extended visibility, aligned planning and analytic capabilities to make proactive tradeoff decisions generating improvements across revenue, cost, assets, risk and predictability. IBP delivers cross-functional alignment of strategic, operational and financial processes to create value in asset-intensive industries. The author will share the operating model, organizational challenges, and best practices from a recent global mining client experience.

3:05 pm
What Financial Options and Strategies for Companies in Varying Stages of Distress are Available Today? What to Do First, as Soon as Possible
Keith McGregor, Partner, Corporate Restructuring Practice, Ernst & Young LLP

3:25 pm
An Attorney's View of Key Legal and Financial Issues Mining and Exploration Companies Should Be Mindful of When Seeking to Raise Capital Today
Cynthia Urda Kassis, Partner, Shearman & Sterling LLP

3:45 pm

Non-Technical Considerations in the Due Diligence Process of Mining Transactions

Robert Livermore, CEM, Principal Ramboll-Environ

“Due diligence” is the review of a facility or business to assess and quantify risks and operating status before an acquisition. Due diligence findings can be used to negotiate the price, general terms, and indemnification provisions in the purchase and sales agreement. In addition to assessing outstanding liabilities, necessary capital improvements, and the adequacy of operating budgets, due diligence should include “nontechnical” considerations, such as local community acceptance and relations, and the effect on the company’s public image, operations and post-closure strategies. This paper will discuss how these considerations can be addressed in the due diligence process and factored into the transaction.

4:05 pm

A Mining Executive’s View of Raising Capital in Mining Today, Including Raising Debt, Equity, Hybrids, and Managing Relations with Investment Bankers and Shareholder Communications

M. Smith; Largo Resources, New York, NY

4:25 pm

An Independent Advisor’s View of Raising Capital for Mining Ventures Today

R. Reeves; RGR Advisory Services, New York, NY

MONDAY, FEBRUARY 20

AFTERNOON

2:00 pm **Room 507**

A Survival Guide for Promotion & Tenure

Chairs: *H. Miller, Colorado School of Mines*
R. Honaker, University of Kentucky, Lexington, KY

2:00 pm
Introduction

2:05 pm
Lessons Learned from Promotion & Tenure Decisions in Mining and Mining-Related Programs

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

The dynamic nature of the university environmental has resulted in significant and more challenging demands on faculty members. One of the more important changes is that funding for public institutions has shifted from primarily state-funded to revenues driven from tuition, research and philanthropic sources. As a result, the expectations for promotion and tenure have shifted to require the development of a sustainable and impactful research program while providing exceptional teaching performances and dedicated service to the university and profession. The presentation will discuss, in general terms, the lessons learned from promotion and tenure cases involving mining engineering and mining-related faculty.

2:25 pm
Strategies to Earn Promotion and Tenure

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

Most departmental promotion, retention and tenure guidelines use nebulus terms such as satisfactory and exceptional. They provide broad guidelines for scholarly activity, teaching, service and reputation. But what do they really mean? This presentation will discuss how one can determine what your department and university is really looking for and how to turn that information into self-imposed quantifiable goals. Once goals are established then progress can be evaluated and specific objectives modified depending on your career development. The end result should be a well rounded promotion dosier, which is well received by your department and university.

2:45 pm
Creating Successful Promotion and Tenure Dossiers
M. Poulton; Lowell Institute for Mineral Resources, University of Arizona, Tucson, AZ

The concept of tenure in academia dates to the year 1158 under the Holy Roman Emperor Frederick Barbarossa. In the US, Harvard College introduced tenure in the early 1800s to prohibit donors or the clergy from removing faculty members with unpopular views. Tenure is still misinterpreted by many as a lifetime job guarantee. The reality is, approximately 33% of college and university faculty members are tenured. Tenure is very difficult to achieve and in any given annual review cycle about 20% of faculty are released before achieving promotion. Tenure is not an entitlement or a means of job security; faculty members undergo a post-tenure performance review every year and can be dismissed for poor performance after going through due process. The tenure review process recognizes excellence in teaching, research, and service but research reputation is weighted most heavily. Faculty members are rewarded for creating knowledge not just disseminating old knowledge. In this presentation we will look at how to prepare a strong promotion and tenure dossier for faculty in mineral resources disciplines with a focus on research-intensive doctoral universities.

3:05 pm
Navigating the Waters of Tenure and Promotion
V. Kecojevic; Mining Engineering, West Virginia University, Morgantown, WV

Teaching, research, and service to the university, society and profession constitute the heart of the mission of land-grant universities. Therefore, for an award of tenure and promotion, tenure-track faculty undergo a particularly rigorous evaluation involving an assessment of accumulated and demonstrated accomplishments in these areas and the likelihood that the faculty member's level of performance will be maintained in the future. The objective of this presentation is to guide tenure-track faculty members in mining engineering in navigating the waters of tenure and promotion, i.e., enhance an understanding of the promotion and tenure process; a nature of competitive academic environment, and academic requirements related to teaching, research and service. This presentation is based primarily upon the author's experience going through the rigorous promotion and tenure process at two strong research-based land-grant universities, chairing the promotion and tenure committees, reviewing dozens of promotion and tenure files at both national and international levels, and mentoring tenure-track faculty members in mining engineering.

3:25 pm
Promotion and Tenure from the Assistant Professor Point of View
N. Ripepi; Mining Engineering, Virginia PolyTech Inst State U, Blacksburg, VA

Funding: PI; Co-PI; Career Award; and % Credit. Funding Sources: DOE; NIOSH; NSF; and EPA. Publications: Journal; Reviewed Conference Proceeding; Abstract Reviewed Conference Proceeding; Not-reviewed; Poster; Submitted; Under review; In Press; Accepted with minor revisions; Major revisions!; 1st author; Corresponding author; 2nd author; Last author; and Advised student as 1st author*. Ranking Publications: Impact Factor; Citations; H-Index; i10 Index; G-index; ResearchGate; Scopus; Google Scholar; Elsevier; SME Transactions. Teaching: Student evaluations; Credit hours; Weighted credit hours; Grad class; Undergrad class; Special study; GPA; and Research hours. Students: PhD; MS; Masters of Engineering; Qualification exam; Prelims; Defense; Dissertation; Thesis; and Undergraduate research. Service: Panels; Session chair; and Committees: Graduate, Space, Honorifics, Curriculum and Search. Titles: Department Head; Named Full Professor; Professor; Associate Professor; Associate Professor without Tenure; Assistant Professor; Research Professor; Research Associate Professor; Research Assistant Professor; Research Scientist; Research Associate; and Post-Doc. What really matters?

MONDAY, FEBRUARY 20

AFTERNOON

2:00pm **Room 107**

Bulk Material Handling: New Technology in BMH

Sponsored by Siemens

Chair: *T. Burchett, Rexnord*

2:00 pm
Introduction

2:05 pm
Benefits of High Powered Gearless Conveyor Drives – Applied to Medium Power Conveyors

U. Richter; Material Handling, PAPI, ABB Automation GmbH, Cottbus, Germany

Recent installations of high powered Gearless Conveyor drive systems have shown the promise of increased reliability, improved system efficiencies and reduced maintenance which results in higher productivity, increased revenue and lower operating costs for mine operators. Currently, this new technology is cost effective in conveyor systems using multiple drive modules with power ratings above 3.5 - 4 MW each. This paper examines a method of applying these advantages to conveyor drive systems with power modules in the 500 to 3000kW range. The global significance of this is apparent when the number of conveyors using these power ratings is considered. While this technology has not yet been commercially implemented, some design criteria and cost implications are considered and possible future solutions are discussed.

2:25 pm
Barroso Flyingbelt, 9 Month of Operational Experience vs. Design Parameters
S. Cattaneo[2] and C. Ullmann[1]; [1]Global Application Engineering, Sempertrans Conveyor Belts, Moers, NRW, Germany and [2]Sales, Agudio Leitner, Torino, Italy

The longest Flyingbelt in the world started its operation life at LafargeHolcim's Barroso Plant in June 2016. After running for nine months it is possible to make the first proper comparison of actual data and design parameters like power consumption, availability and maintenance requirements. The new cement plant in Barroso is one of the most modern and efficient plants in Brazil. Thus LafargeHolcim's Engineers were looking for the best available technology (investment costs, environmental impact and operational costs) to convey Limestone from the quarry, which is 4.5 miles away from the cement plant. They found the solution in Agudio's Flyingbelt. A conveyor system suspended on ropes and equipped with a special Sempertrans conveyor belt. This solution allowed the shortest possible connection between quarry and cement plant, with the least environmental impact. Besides the information about nine month of operation, this technical session will also cover key design aspects of the Barroso project from a cableway point of view and a conveyor belt point of view. Experiences about the installation of a 9 mile endless conveyor belt, suspended 100 ft above ground will also be shared.

2:45 pm
Innovative Ways of Transporting Bulk Material: How to Transport Ore Down 400 Meters Vertical Drop in Only 1.3 km: the RopeCon® from Doppelmayr
m. jamaty and D. Mazagg; Doppelmayr Transport Technology, Doppelmayr, Wolfurt, Austria

As ore is getting harder and harder to reach, innovative ways of transporting bulk material is becoming a necessity to lower operating costs while taking care of safety and the environment. Doppelmayr, the world leader in ropeways, has developed material transport solutions for the mining industry. The RopeCon®, an aerial conveyor rolling on suspended ropes with no idlers, supported by only one tower, is transporting Torex Gold's ore with no detour while generating power. To connect the El Limón gold ore pit with the processing plant it was necessary to overcome an altitude difference of approx. 400m in steep terrain. Minera Media Luna, S.A. de C.V. (MML), 100% owned subsidiary of Torex Gold Resources Inc., opted for the RopeCon® as a means to transport 1,000 metric tons of gold ore per hour into the valley over a distance of 1.3km. Along with other aspects, safety and environment were key considerations in prompting the decision.

3:05 pm
Successful Validation of the New Chevron-Megapipe Conveyor, Steeply Inclined Continuous Haulage in Hardrock Open Pit Mines
C. Dirscherl[1], P. Börsting[2] and A. Minkin[3]; [1]Minerals, Siemens Industry Inc., Littleton, CO; [2]Mining, thyssenkrupp Industrial Solutions AG, Essen, Germany and [3]ContiTech, Continental, Northeim, Germany

Joining some of their respective core competencies in belt-, conveyor- and direct drive development and design, ContiTech, thyssenkrupp and Siemens lately introduced the Chevron-MegaPipe® Conveyor. It is set to help reduce conventional heavy-duty truck traffic and the resulting high operating costs in open pit mines. High-strength ribbed steel cable Chevron-MegaPipe®s with a nominal strength of up to 9,500 N/mm and an outer diameter of up to 900 mm facilitate cost-effective conveyance of ore and overburden with lump sizes up to 350 mm over mine slopes with angles of inclination up to 45°. The challenges in question comprise the maximum inclination possible for secure operation, the chevron cleat performance and the handling of oversized lumps in the material flow to avoid jamming or structural damages. The validation methods used for proof-of-concept are described and the results are then discussed in this article. The paper closes with an updated feasibility study based on an exemplary yet typical open pit mine application to economically compare the Chevron-MegaPipe Conveyor with alternative conveying and haulage concepts.

3:25 pm
Reliability-Based Capacity Determination Model for Semi-Mobile in-Pit Crushing & Conveying Systems (SMIPCC)
R. Ritter; Proposal Department, TAKRAF GmbH, Lauchhammer, Germany

Current capacity calculation models often over-estimate actual throughput resulting in under-utilisation of downstream processes and a shortfall in revenue. An alternative approach has been developed based on a structured time usage model specific to SMIPCC systems, that models the interface between discontinuous loading and truck haulage as well as the continuous crushing, conveying and discharge processes while recognising the interdependencies between individual mining processes and system element disturbances. This approach is based on a stochastic simulation model that accounts for performance variability of individual processes and unplanned failures of system elements. A case study based on a hypothetical mine environment to analyse the system behaviour with regards to time usage model component, system capacity, and cost as a function of truck quantity and stockpile capacity. Furthermore, a comparison between a conventional truck & shovel system and SMIPCC system is provided. Results show that the capacity of a SMIPCC system reaches an optimum in terms of cost per tonne, which is 24% lower than a truck and shovel system.

MONDAY, FEBRUARY 20
AFTERNOON

2:00 pm **Room 106**
Career Development Right from the Start – Defining Your Professional Path

Chairs: *M. Montenegro, MMG, Ltd*
K. Gardner, Newmont, Elko, NV

2:00 pm
Introduction

This session will feature presentations from mid-senior level mining industry professionals about their specific career paths. A career in the mining industry can take many different forms from Industry to Services to Government to Academia. Each of these areas include diverse professions. It can be hard to understand the implications of making (or not making) different moves as a professional early in one's career. One of the best ways to evaluate different paths and their potential fit is to understand the paths of senior professionals. This session is intended to answer the burning question of "How did they get there?"

MONDAY, FEBRUARY 20

AFTERNOON

2:00 pm **Room 711**

Coal & Energy: Best of Ground Control

Chairs: *S. Tadolini, Minova, Lakewood, CO*
M. Murphy, National Institute for Occupational Safety and Health, Pittsburgh, PA

2:00 pm
Introduction

2:05 pm

Evaluation of Potential Impacts to Stream and Ground Water Due to Underground Coal Mining

C. Newman, Z. Agioutantis and G. Boede Jimenez Leon; Department of Mining Engineering, University of Kentucky, Lexington, KY

Ground movements due to longwall mining have the potential to damage the hydrological balance within as well as outside the mine permit area in the form of increased surface ponding and changes to hydrogeological properties. Recently, the Office of Surface Mining, Reclamation and Enforcement has completed a public comment period on a newly proposed rule for the protection of streams and groundwater from adverse impacts of surface and underground mining operations. With increased community and regulatory focus on mining operations and their potential to adversely affect streams and groundwater, there is now a greater need for better prediction of the possible effects mining has on both surface and sub surface bodies of water. As mining induced stress and strain within the overburden is correlated to changes in the hydrogeological properties of rock and soil, this paper investigates the evaluation of the hydrogeological system within the vicinity of an underground mining operation based on strain values calculated through a surface deformation prediction model.

2:25 pm

Void Fill and Support Techniques to Stabilize Drift Excavated Through a Transition Zone Mined by a TBM at the Stillwater Mine

J. Johnson[1], C. Jacobs[1], M. Ferster[1] and S. Tadolini[2]; [1]Stillwater Mining Company, Nye, MT and [2]Minova, Georgetown, KY

Stillwater Mining Company is the only U.S. producer of platinum group metals (PGMs) and the largest producer outside of South Africa and Russia. The Company controls a considerable portion of the J-M Reef and is currently developing the "Blitz Project," which will provide a main haulage level, ore pass systems, backfill plants, and flow-through ventilation to increase production and ensure sustainable extraction of this critical strategic mineral. While driving two subparallel footwall laterals to about 8,125 m (26,000 ft) long, one of the development drifts experienced a massive fall in a geologically disturbed area created by a dike intrusion. Combinations of a void fill material (Tekseal), polyurethane injection, fore poling coupled with steel arches, and supplemental bolting allow safe and efficient advance through this geologically disturbed zone. This paper presents the details of this project.

2:45 pm

Design Concerns for Room and Pillar Retreat Panels in an Eastern Kentucky Mine

T. Klemetti, I. Tulu and M. Sears; Pittsburgh Mining Research Division, NIOSH, Pittsburgh, PA

Why do some room and pillar retreat panels encounter abnormal conditions? What factors deserve the most consideration during the planning and execution phases of mining and what can be done to mitigate those abnormal conditions when they are encountered? To help answer these questions, and to determine some of the relevant factors influencing the conditions of room and pillar (R&P) retreat mining entries, four consecutive R&P retreat panels were evaluated. This evaluation was intended to reinforce the influence of topographic changes, depth of cover, multiple-seam interactions, geological conditions, and mining geometry.

3:05 pm

Evaluation of Drill Hole Geometry on Bolted Roof Beam Performance

D. Burkhard; San Juan Coal Company, Waterflow, NM

Comparative roof beam performance, as measured by delamination within the bolted horizon, was used to evaluate two types of roof bolt drill hole geometries in a development setting. Short encapsulation pull tests had demonstrated a higher grip factor in drill holes featuring helical grooves in the side walls in comparison to drill holes featuring continuous smooth to slightly rough walls. The study incorporated the two geometries during development mining in which fully grouted mechanically anchored bolts were installed as primary roof support. The study site, in an entry adjacent to a longwall panel, was instrumented with extensometers and data collected during longwall retreat. Statistical analysis was conducted to validate null and alternative hypotheses used to compare drill hole geometries. Analysis yielded no statistically significant difference between drill hole geometries. Inspection of the data does reveal less delamination within the smooth walled site in comparison to the site containing grooved hole geometry.

3:25 pm

A Practical Application of Photogrammetry to Perform Rib Characterization Measurements in an Underground Coal Mine Using a DSLR Camera

B. Slaker and K. Mohamed; Pittsburgh Mining Research Division, NIOSH, Pittsburgh, PA

Understanding coal mine rib behavior is important for inferring pillar loading conditions and ensuring the safety of miners regularly exposed to ribs. Photogrammetry is a fast, cheap, and precise supplemental measurement tool in comparison to extensometers or tape measures. The practical use of photogrammetry was tested at the NIOSH Safety Research and Experimental Coal Mine. A Digital Single-Lens Reflex camera was used to perform photogrammetric surveys. Experiments were performed using different lighting conditions, distances to subject, and camera settings. The lighting method was insignificant if the scene was appropriately illuminated and the distance to the subject has a minimal impact on accuracy. Focal Ratio changes affect the depth of field and image quality where multiple angles are necessary to survey cleat orientations. The suggestions proposed are designed to increase the quality of photogrammetry inputs and outputs and minimize processing time. They serve as a starting point for an underground coal photogrammetry study.

3:45 pm

A Review of the Geomechanics Aspects of a Double Fatality Coal Burst at Austar Colliery in NSW, Australia in April 2014

B. Hebblewhite; School of Mining Engineering, UNSW Australia, Sydney, NSW, Australia

A coal burst occurred on 15 April, 2014 at the Austar Coal Mine, located west of Newcastle, NSW, Australia. The burst resulted in fatal injuries to two men working as part of the mining crew at the development face. At the time, a continuous miner was being used to mine a longwall development gate road through heavily structured coal, at a depth of approximately 550m. A number of pre-cursor bumps had occurred on previous shifts, emanating from the coal ribs of the roadway, in proximity to the coal face. This paper reviews the geological, geotechnical and mining conditions and circumstances leading up to the coal burst event; and presents and discusses the avail-

able evidence and possible interpretations relating to the geomechanical behaviour mechanisms that may have been critical factors in this incident. The paper also discusses some key technical and operational considerations of ground support systems and mining practices and strategies needed for operating in such conditions in the future.

MONDAY, FEBRUARY 20

AFTERNOON

2:00 pm **Room 702**

Coal & Energy: Carbon Regulations & Management

Chairs: *M. Mohanty, Southern Illinois University Carbondale, Carbondale, IL*
A. Lundin, HDR, Englewood, CO

2:00 pm

Introduction

2:05 pm

Carbon Capture, Transport and Geologic Storage: a Review

A. Srivastava and S. Soarabh; Raw Materials, TATA STEEL, Lucknow, Uttar Pradesh, India

Carbon capture and storage can simply be defined as capturing of waste CO_2 from industrial sources at various stages (ex. pre-, post- combustion etc.), transporting it to a storage site (through pipelines etc.) and then depositing it underground so that the CO_2 will not re-enter the atmosphere for a geologically significant long time. Because of the low prices of fossil fuels and lesser statutory restrictions in developing countries (which are primarily dependent on this form of energy), aided by slow development and high cost of alternative energy projects, the CO_2 emission into the atmosphere has been ever increasing. The long lasting effects of such high levels of CO_2 in atmosphere can portray an image of an impending catastrophe but a better approach would be to avoid those and look into the solutions to minimize the CO_2 levels in atmosphere. This paper offers an insight into the technologies and the techniques that have been developed for carbon capture followed by transporting methods (and their problems) and ends with discussing the various storage technologies.

2:25 pm

Techno-Economic Study of Underground Coal Gasification with Carbon Capture and Storage in India

S. Soarabh and A. Srivastava; MINING, TATA STEEL LIMITED, Noamundi, Jharkhand, India

The insitu conversion of deep-seated underground and unmineable coal for heating and energy generation through UCG has stability and controllability to offer, relative to present coal exploitation methods that offset economic statistics. With the further predilection for clean energy, the idea is to couple the Carbon Capture and Storage technology with UCG at the identified sites at Kasta Block in Raniganj, Kaitha Block in CCL and Theosgara C Block of WCL. The void generated from the enervated coal and goafed out areas of abandoned mines in near proximity is used for CO2 sequestration and elimination of carbon emissions. The conveniently high electrical permeability and permittivity of lignite deposits in in Nevyeli region makes it amenable to electric induction heating insitu facilitating energy extraction from deposit. This paper delineates the techno-economics of energy production from UCG with CCS using a cost-benefit model developed using MATLAB –SIMULINK. The Cost of Electricity (COE) has been calculated assuming a 90% capture. The results show that the coupled UCG-CCS process should be considered as an economic and low carbon intrinsic.

2:45 pm

Using Coal Mine Methane for Fuel

E. Woods; Dresser-Rand, Denver, CO

As a greenhouse gas, coal mine methane is best collected and destructed to reduce envirionmental impact. Collection and conversion of coal mine methane into less harmful constituents via flaring is a favored option to destruct coal mine methane. Modular gas liquefaction systems can be used to convert captured coal mine methane into liquefied natural gas (LNG). Once converted into LNG, it can be used as fuel, displacing diesel, for power generation and for vehicles at the mine or to nearby consumers. Using coal mine methane as a diesel displacement reduces fuel costs and CO2 contribution to the environment.

3:05 pm

Production of Synthetic Aggregate from Coal Ash and Quarry Ponded Fines

H. Akbari, R. Mensah-Biney, G. Dove and J. Simms; NC State University, Asheville, NC

More than 100 million tons of quarry ponded fines are annually produced and added to billion tons of fines already accumulated in the USA. However, because of limited applications, the proper disposal of these fines is a growing concern for aggregate companies. Additionally, over 100 million tons of coal ash is produced each year in the US but only half of which is used as raw feed for some applications and the rest is disposed of in landfills. The main objective of this study was to produce a synthetic aggregate using the geopolymer technology. The feedstocks for the geopolymer-based aggregate were two waste materials disposed of in landfills in North Carolina: coal ash and quarry ponded fines. Alkaline liquids were added to coal ash and mixed with ponded fines to produce a strong binder named geopolymer aggregate. The product was then crushed and size analyzed to determine its suitability to replace the coarse aggregate in concrete applications. Preliminary studies showed that the compressive strength of 2-inch cub mortar samples of synthetic aggregate could be as high as 13 psi. The results of the tests carried out in this study will be presented in this paper.

3:25 pm
Coal & Energy
A. Jain And R. Singh; Mining Engineering, Undergraduation, Dhanbad, Jharkhand, India

THE FUTURE OF COAL BODY There is no single solution that can meet this challenge, particularly in light of the fact that many countries currently depend on coal power plants to meet their energy supply needs. A signifiant expansion of renewable electricity generation is required, as well as continued efforts to developtechnology to reduce the climate impact of existing coal-field power plants. To date, emissions of coal-field power plants have been significantly reduced through flue gas cleaning and by efficiency measures such as coal drying. But additional measures are needed to minimise Co2 emissions to the atmosphere. Two important measures are Carbon Capture and storage technologies and co-firing biomass in coal plants. Carbon Capture and Storage – underground storage of CO2 There are currently several projects underway to develop technologies for burning fossil fuel and simultaneously storing the Co2 released. These methods are known by the collective term CCs (Carbon Capture and storage). At the same time, CCs presents the only technological option to reduce Co2 emissions in countries that are expected to remain dependant on fossil fuels for the foreseeable future.

3:45 pm
Addressing Carbon Regulation and Climate Change in Mine Permits and Planning
A. Lundin; 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 carbon regulation and climate change and how permits and NEPA documents should address the issue. In August, 2016, the CEQ issued final guidance on how climate change should be considered within NEPA documents. However, the guidance on how to address climate change is intentionally open to broad interpretation, and 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 presentation examines a number of emerging regulations, and varying U.S. federal agency approaches to addressing climate change within permits and NEPA documents and offers a path forward on how to effectively and efficiently address climate change in mine permits and NEPA.

MONDAY, FEBRUARY 20

AFTERNOON

2:00 pm **Room 706**

Coal & Energy: Mine Fire Prevention I

Chairs: *L. Yuan, NIOSH, Pittsburgh, PA*
M. Trevits, Xtraction Science and Technology, Inc, Pittsburgh, PA

2:00 pm

Introduction

2:05 pm

Influential Factors for Determination of Interface Boundary in Multiscale Methodology for Simulation of Fire in Road Tunnels

A. Haghighat[1], K. Luxbacher[1] and B. Lattimer[2]; [1]Mining & Minerals Engineering, Virginia Tech, Blacksburg, VA and [2]JENSEN HUGHES, Blacksburg, VA

The simulation and control of the large complex dynamical systems such as a fire in road tunnels can make unmanageably large demands on computational resources, creating a crucial need for efficient model utilization. Coupling of Computational Fluid Dynamics (CFD) models and network modeling simulations (multiscale method) of the fire events can be a useful tool to increase the computational efficiency and accuracy. The boundary between CFD model (near field) and network model (far field) plays a key role in the accuracy of simulations of large systems. This research investigates the influential parameters on the interface boundary changes in the vehicle fire events simulation via a statistical approach. Four main factors such as heat release rate, fire size, tunnel cross section, and inlet velocity were selected for investigation of their effects on the interface location. The CFD model results were used to determine the interface boundary of CFD and network modeling during vehicle fire events in the road tunnels. The two-level fractional factorial design was utilized to investigate different parameters' effect on the various responses at determined interface boundaries.

2:25 pm **17-022**

Characterization of a Mine Fire Using Atmospheric Monitoring System Sensor Data

L. Yuan, R. Thomas and L. Zhou; Office of Mine Safety and Health Research, NIOSH, Pittsburgh, PA

Atmospheric monitoring systems (AMS) have been widely used in underground coal mines in the U.S. for the detection of fire in the belt entry and monitoring of other ventilation-related parameters such as airflow velocity and methane concentration. Although an AMS can detect a mine fire based on a pre-set alarm level, the AMS data provides limited information on the fire characteristics such as the fire growth and exact fire location. This information is critical in making decisions about fire-fighting strategies, underground personnel evacuation and escape routes. In this study, a methodology was developed to calculate the fire heat release rate using AMS sensor data for carbon monoxide (CO), carbon dioxide (CO_2), and airflow velocity. Full-scale mine fire experiments were conducted in an experimental mine using AMS with different fire sources to test this methodology. The calculated heat release rate using sensor data was compared with the value determined from the mass loss rate of the combustible material using a digital load cell. The experimental results show that the heat release rate of a mine fire can be calculated using AMS sensor data with a good accuracy.

2:45 pm 17-035

Design of a Laboratory Scale Wind Tunnel for Studying Mine Fires

J. Davis, E. Jong and K. Luxbacher; Mining and Minerals Engineering, Virginia Tech, Blacksburg, VA

A wind tunnel was designed to examine air flow, heat transfer and layering near an active fire at a working face. This tunnel simulates an active entry in an underground coal mine including an attached cross-cut of similar dimensions. A steel rectangular duct 1 ft tall, 3 ft wide and 10 ft long composes the main body of the tunnel and represents a full-scale mine entry. Air flow is generated by an exhausting centrifugal fan attached to one end of the cross-cut. This fan was sized to supply air velocities based on Froude scaling. A six-inch propane burner is used to simulate fires of various heat release rates at the working face. Thermocouples are used to map heat layering in the tunnel. Ports are installed for the introduction and sampling of tracer gases into and from the system. Barometric pressure, differential pressure and temperature sensors are also included to monitor environmental conditions. Design and testing of the system are detailed, including design of scaling for fire and flow phenomena. Finally, proposed use of the tunnel for better understanding of mine fire phenomena and prevetion are examined.

3:05 pm

Technique for Testing Coals' Propensity of Spontaneous Combustion with High Moisture Content

X. Wang[1], Y. Luo[2] and B. Vieira[2]; [1]Safety Science and Engineering, Liaoning Technical University, Fuxin, Liaoning, China and [2]Mining Engineering, West Virginia University, Morgantown, WV

Low rank coals, such as the sub-bituminous coals in the Powder River Basin, typical have high risk of spontaneous combustion. It is ideal to have their propensities for spontaneous combustion to be tested and quantified. However, due to their high moisture contents, the standard testing procedures, drying the samples before the oxidation testing, are often incapable of completing the experiments within reasonable time duration or producing reliable propensity indices. A new experimental procedure has been proposed to test the low rank coals with high moisture contents on the standard R70 adiabatic laboratory testing setup. The new procedure considerably reduces the required experimental time corresponding to the field spontaneous combustion phenomena. Tests have been performed on coal samples collected from the Powder River Basin and from South America coal fields with reasonable propensity indices.

3:25 pm

Using Teamwork and Technology to Enhance Fire Safety on Mobile Equipment and Other Minesite areas

K. Carver; Global Accounts, Tyco, Evansville, IN

Through utilizing their technology and teamwork core values in a data-driven approach, Ansul and Caterpillar have have been working together to improve fire safety on mobile equipment. Employing a six sigma approach from Fire Risk Analysis through early engineering design through 3d design/simulation through live testing on pilot machines, the overall safety and dependability of the mobile machine has been enhanced. Through computer modeling, the machine is designed for the optimal application of a well-designed fire suppression system. Additionaly, serviceability and reliability are improved by integrating the fire protection components with the machine. Off-site analytics and service schedule integration are possible, as well as enhanced uptime for the end user. Additional anciallary benifits are realized by leveraging mobile equipment fire protection schemes for other minesite areas such as conveyer headers, battery charge stations, and other fixed special hazards. In this session you will learn: 1) What is being done to design safety into equipment. 2) What is being done to make ordinary and routine maintenance safer. 3) How does the adoption of this technology cause other issues.

3:45 pm

The Application of Expandable Filling Material in Fire Prevention and Extinguishment for Coal Spontaneous Combustion in Goaf of Face in four-section in Wumuchang Coalmine, Inner Mongolia, China

C. Wang, Y. Xiao, J. Deng, H. Wen and X. Liu; School of Safety Science and Engineering, Xi'an University of Science and Technology, Xi'an, Shaanxi, China

The Wumuchang coalmine located in Ewenki, Hulunbuir, Inner Mongolia, China is the first underground mining of Huaneng Group Ltd. independent investment construction. The mining method is used the longwall caving mining along strike which the technology is fully mechanized top-coal caving. During the face stopped and retracement, the concentration of CO continued to rise and C_2H_4 began to occur, which represented that the spontaneous combustion of coal in the goaf. Some measurements were take control for the coal fire. The face was closed to inject nitrogen for inerting the whole goaf, the fire-fighting roadway was constructed parallel to the intake air crossheading of the face, which the boreholes were drilled to the goaf. The liquid CO_2 and fly ash slurry were injected to the fire area cooling down the temperature and decreasing the concentration of oxygen. Furthermore, for effectively isolate the air leakage and oxygen supply in the goaf, the expansion filling material was required to inject to ultimately eliminate the high-temperature region. Finally, the data for temperature and C_2H_4, CO monitored indicate that the coal spontaneous combustion has been effectively controlled.

MONDAY, FEBRUARY 20
AFTERNOON

2:00 pm **Room 704**
Coal & Energy: Profiting with Technology in a Cyclical Economy

Chair: *J. Nolke, Caterpillar*

2:00 pm
Introduction

2:05 pm
Deliver Efficient Compliance to Plan While Managing Your Cost Utilizing Technology
R. Howell; Mining Technology Enabled Solutions, Caterpillar, Denver, CO

Most sites are leaving between 10-30% productivity on the table and don't realize it. How do identify, reduce and eliminate that at your site. Measure: What is your overarching metric to ensure that all the little knobs you turn and levers you pull are all moving in a positive direction? Do you know what to measure? What are your units of measure: tons, money, time, machines? Is your measuring stick accurate? Most sites rely on a measuring stick that is inaccurate due to the people and processes that support the system. Once the data is recorded, do you have it organized in a way to analyze it and prioritize the wins with the least amount effort and cost? Manage: Once you have a prioritized order, do you know what is possible? Do you know how to affect it? Do you have a good short term interval control process and tool in your Pit Supervisors o controller hands to ensure they can affect the outcome that shift? Optimize: Optimization can occur by removing as many of the steps, people, time and cost as possible. How is this possible? Technology. By handing the control over to technology, you can get your people and processes working on the next big goal.

2:25 pm **17-119**
The Introduction and Advancement of Remote Roof Bolting in South African Coal Mines
R. Burgess, D. Gill, J. Steyn and W. Kyslinger; J.H. Fletcher & Co., Huntington, WV

There is always a demand in the mining industry to improve the safety and efficiency of roof bolting. The recognized types of machines currently used in South Africa are always under constant review. The majority of the machines in South Africa are the "Man in Position" style. There are currently over 200 of these machines in South Africa, with the bulk of the machines being twin-boom units. When operated correctly, these machines are safe, versatile, reliable and productive. However, with the operators located close to the drilling and bolting operations, they can be exposed to operational hazards. Anglo American was interested in working with Fletcher to develop a remote style machine with simplified controls that maintained the productivity of the

SME TECHNICAL PROGRAM: MONDAY

twin-boom machines. After several prototypes, the current model was developed. The chassis was designed for better operator comfort. A dual mast drill module was implemented to reduce the total time to bolt a cut. The design was all about producing an efficient machine that has a remote operators station. This paper will explain the evolution and technological advancements from earlier prototypes to the current production machine.

2:45 pm

The Critical Role of Distributed Generation for Reliable, Affordable Power Systems

D. Leligdon and J. Abiecunas; Black & Veatch, Denver, CO

The economics of distributed generation and microgrids are changing rapidly. Modern microgrid solutions are becoming an important part of sustainable, reliable and cost-effective electric systems. Distributed or renewable energy solutions are a competitive complement to central station coal or combined cycle power plants, particularly given cost, schedule and sustainability advantages. Whether in off-grid, grid-edge or high-resiliency situations, distributed generation and microgrid solutions can be the best business case for the right applications. This paper provides an overview of modern microgrids, including the functionality and optimal configuration of these systems and lessons learned from recent projects. The economics of microgrids compared to various power supply alternatives for remote and critical facilities is also evaluated to establish guidelines for determining when distributed energy solutions are the best alternatives for utilities and energy consumers alike.

3:05 pm 17-117

The Effects of Detonation Wave Collisions on Rock Throw

P. Cahill[1], C. Johnson[1] and J. Nawrocki[2]; [1]Mining Engineering, Missouri University of Science and Technology, ROLLA, MO and [2]Dyno Nobel, Salt Lake City, UT

Cast blasting is the primary means of overburden displacement in a surface coal mine. It serves two purposes; fragmenting the rock and throwing it directly to its spoil pile using explosive energy. Increased throw minimizes costs by reducing the amount of material that needs to be re-handled. Prior studies have shown that by only changing blast hole timing with the same blast design, fragmentation and throw alters. It is necessary in cast blasting to optimize both fragmentation and throw, since larger fragments will require more wasted energy to throw the same distance. In an operating mine in Georgia, an optimum inter-hole delay for fragmentation has been found by studying timings from 0ms to 45ms. Instantaneous timing between holes increased the throw by over 100ft, but fragmentation was poor. Shock and detonation wave collision is a potential reason for this increased throw. This paper investigates this optimized inter-hole timing while altering top and bottom column primer time to potentially improve throw while maintaining optimum fragmentation. Timings studied are top initiation, bottom initiation, and top and bottom simultaneously.

3:25 pm 17-038

Development of a Six Drillhead Roof Bolting Machine

W. Kyslinger; Engineering, J. H. Fletcher & Co., Huntington, WV

The objective was to produce a machine capable of drilling & installing 6 bolts simultaneously, with a limited number of operators. The goal of the mine is to decrease the time to bolt a cut to improve the safety level of the current roof bolting method, improve efficiency & to improve the bottom line cost of entry development. The customer wanted 4 drills at the front of the machine dedicated to installing roof bolts and then another 2 drills behind them dedicated to rib bolts. This dictated the requirement of latched controls, which would allow the operator to start drilling one hole & then latch the controls to be able to move on to the next. The 6 head roof bolter allows fewer operators to drill & install roof & rib bolts, which in turn lowers the miners' roof exposure per cut. This design reduces the operator's exposure from the inherent pinch points & rotary hazards once he has engaged the latch drilling. Therefore the machine will help to decrease the time to bolt a cut, improving productivity while enhancing the ability to operate the machine safely.

3:45 pm

Intervention Effectiveness of Distributive Leadership in an Underground Coal Mine

P. Guild and T. Hethmon; Mining Engineering, University of Utah, Magna, UT

There is a general consensus in the mining industry that effective leadership is essential for strategic and tactical success across many mining functions, including safety. Leadership applications are critical for the establishment and effectiveness of safety and health management systems in mining. This project involves research in the form of an intervention effectiveness study involving the decentralization of leadership (i.e., distributed leadership) in an underground coal mine. The study cohort consisted of one underground, continuous miner crew, who participated in a restructure of their traditional, centralized leadership model. The restructure occurred through individual leadership training, personal coaching and work process reviews. This project is very unique for its application in a working coal mine under "real world" conditions. As such, there were limitations to the experiment design that resulted in limited statistical power and limited coherence with research design. However, the rarity of applying a leadership intervention in a working, section coal mine offers a unique lense through which to review the role of leadership in mining.

MONDAY, FEBRUARY 20

AFTERNOON

2:00 pm **Room 708**

Coal & Energy: Surface Processes and Practices

Chairs: *D. Bogunovic, North American Coal, De Kalb, MS*
M. Heger

2:00 pm

Introduction

2:05 pm

Novel use of Draglines for Coal Mine Final Reclamation

J. Salomon; Luminant Mining, Fairfield, TX

The Big Brown Mine in Texas was wrapping up its 40+year production life and was left with a 21,000 ft long final pit in need of reclaim. Presentation will discuss the engineering that went into this project as well as some of the novel use of draglines to perform extended reclamation activities. Also included will discuss some of the many lessons learned from this endeavor.

2:25 pm

Equipment Alternatives for Historic Mining Practices

J. Wientjes, J. Mills, R. Kafka and L. Tolley; Application Engineering, Komatsu America Corp., Peoria, IL

As a leading manufacturer and supplier of large-scale mining equipment, Komatsu frequently is requested by industry to investigate the feasibility of integrating traditional mobile mining equipment into operations using alternative equipment and mining methods. For example, the Komatsu America Corp. (KAC) Application Engineering group has recently been involved in multiple studies involving replacing ineffective dragline mining practices with traditional mining equipment and methods. These analyses have not only included the expected performance of mobile units, but the projected impact to the dragline mining methodology, overall performance and economics of the revised mining system, and sensitivities thereof. This paper will review the key processes and calculations used to conduct these studies. Effort will be made to convey these procedures both numerically and graphically in a concise step by step manner. The attendee should be able to obtain a conceptual understanding of the evaluation logic utilized when integrating mobile equipment into a common dragline operating practice.

2:45 pm

Integrated Production Management System (IPMS)

M. Badani Prado[1] and D. Bogunovic[2]; [1]Engineering, North American Coal Corporation, De Kalb, MS and [2]Operations, North American Coal Corporation, De Kalb, MS

Integrated Production Management System (IPMS) is an internally developed software that manages production, delays, equipment, energy consumption, employee information, certifications, overtime, and other information. IPMS produces highly detailed reports on user demand of production, availability, delays, energy consumption, etc. The first version of IPMS is in use since 2008 and has been used successfully since then. This paper discusses some challenges this software encountered due to operating system updates, the solution developed for addressing those challenges, and a review of the new version developed.

3:05 pm
Block Size and Open Pit Mining Costs

A. Hekmat[1], M. Osanloo[2] and R. Gómez[1]; [1]Metallurgy, Unicersity of Concepcion, Chile, Professor assistant, Concepcion, Bio Bio, Chile and [2]Mining and metallurgy, Amirkabir University of Technology, Professor, Tehran, Tehran, Iran (the Islamic Republic of)

Computer planning and design of mining projects is mainly done based on block model, in which the block size is usually determined based upon exploration database in order to achieve the most precise grade and tonnage of the deposit. Even though in production stage block dimension effects the capital and operating costs in addition to profitability, efficiency and capacity of equipment, these parameters are not considered when defining the block size. Therefore, despite the ability of some algorithms to determine the optimum solution, the optimality of these algorithms is in doubt; since these algorithms are based on some assumption such as the known block size. This study uses the industry standard for mining cost estimation as well as O'hara method to define the capital and operation costs of drilling, blasting, loading and haulage of different sizes of blocks. The results of the research showed that increasing the block size will decrease the operating costs while the capital cost will increase.

3:25 pm
Methodology for Surface Coal Mine Reclamation Using Cast Blasting

T. Worsey[1], S. Kan[1], N. Rouse[1] and J. Silva[2]; [1]Mining and Energy, RESPEC, Lexington, KY and [2]Mining Engineering, University of Kentucky, Lexington, KY

Design tools for estimating cast-to-final percentages from cast blasting are limited and none of these available tools consider cast blasting for surface coal mine reclamation application. In addition to production, cast blasting can also be used in surface coal mine reclamation. The only clear difference between both applications of blasting is the percentages of final cast for each condition. Typically, the percentages for cast blasting in production are lower compared to percentages for cast blasting in reclamation. This difference is primarily due to the fact that reclamation cast blasting does not require uncovering coal or blasting to top of coal. Using the volume from the cast blast to help backfill the pit is the main goal. The methodology explained in this conceptual paper uses simple cast blasting design tools to estimate the cast for a blast designed to backfill a pit and reclaim highwalls at a surface coal mine while using minimal site-specific data. Cast blasting was used to reduce the bonding amount required by the regulatory agency. However, costing is not the focus of this paper and will be addressed in future publications.

MONDAY, FEBRUARY 20

AFTERNOON

2:00 pm **Room 102**

Environmental: From Gold King to Laguna

Chairs: *V. McLemore, NMBGMR/NM Tech, Socorro, NM*
B. Frey, New Mwxico Tech, Socorro, NM

2:00 pm

Introduction

2:05 pm

What Have we Learned from Legacy Mine Accidents and Failures in Western United States?

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

At the time the General Mining Law of 1872 was written, there was no recognition of the environmental consequences of direct discharge of mine and mill wastes into the nation's rivers or their impact on the ecosystem. Miners operating on federal lands had little to no requirement for environmental protection until the 1960s-970s. It is important to recognize that these early miners were not breaking any laws, because there were no laws to break. There are tens of thousands of inactive or abandoned mine features throughout western U.S. Many of them pose only a physical hazard, which is easily but costly to remediate. Mine accidents that were once common in the late 1800s to 1900s, are rare today, but still occasionally happen. On August 5, 2015, EPA personnel released ~3 million gallons of acid water from the Gold King mine, CO into the Animas River, resulting in re-evaluation of reclamation of mines throughout the U.S. Legacy issues still remain and should be inventoried. Today, one important aspect of mine planning in a modern regulatory setting is the philosophy, actually, the requirement in most cases, that new mines and mine expansions must have plans and designs for closure.

2:25 pm

How Could the Gold King Mine Water be Passively Treated?

J. Gusek; Sovereign Consulting Inc., Lakewood, CO

The images of the August 2015 blowout of the Gold King mine pool above Silverton were dramatic. The chemical treatment measure that was implemented is expensive and is certainly temporary; clearly, the thought of addressing this situation in-perpetuity with active treatment is unacceptable on a number of levels. Implementing low-tech passive treatment techniques (aka constructed wetlands), coupled with innovative source control technologies are the first logical step on a "pathway to walk away" for this site and perhaps others in the Animas River Basin. This paper examines several logical concepts for passively treating Gold King Mine discharge using processes developed by Mother Nature herself. While passive treatment systems are viewed as a low-cost and low maintenance, they are not maintenance-free despite the evidence that natural analogues have been functioning in Colorado for millennia without human intervention. Still, they are a logical, natural, and cost-efficient alternative to chemical treatment forever.

2:45 pm

Surface-Water and Groundwater Quality in Northwestern New Mexico after the Gold King Mine Release

J. Blake[1], S. Timmons[2], L. Bexfield[1], J. Brown[1] and E. Mamer[2]; [1]U.S. Geological Survey, Albuquerque, NM and [2]New Mexico Bureau of Geology and Mineral Resources, Socorro, NM

The Animas River in Colorado and New Mexico (NM) was exposed to three million gallons of water and sediment released from the Gold King Mine on August 5, 2015. During this time, elevated concentrations of iron, manganese, arsenic (As) and lead (Pb) (among other metals) were observed in the surface water. The Animas River enters NM near Cedar Hill and joins the San Juan River at Farmington, NM, one of several communities that rely on the Animas and San Juan rivers for drinking water and irrigation. Between Cedar Hill and Aztec, NM, the Animas River is a gaining reach on a coarse scale; however, observations on a fine scale adjacent to the river suggest it can be a losing reach in places, especially during the winter months when the water table is lowest. Constituents such as major ions, metals, including As, and Pb, as well as field parameters such as pH, temperature, specific conductance, and turbidity, are currently being monitored in surface water by the U.S. Geological Survey and in groundwater by the New Mexico Bureau of Geology and Mineral Resources.

3:05 pm

The Characterization of Abandoned Uranium Mines in New Mexico

J. Asafo-Akowuah[1], A. Winton[1] and V. McLemore[2]; [1]Mineral Engineering, New Mexico Institute of Mining and Technology, Socorro, NM and [2]New Mexico Bureau of Geology and Mineral Resources, New Mexico Institute of Mining and Technology, Socorro, NM

Although the physical safety hazard of some U mines in NM have been mitigated, especially in the Grants district, there still remain many inactive/abandoned U mines that are yet to be prioritized for reclamation. Miners operating on federal lands had little to no requirement for environmental protection until the 1960s and 1970s, although the dumping of mine wastes and mill tailings directly into the nation's rivers was halted by an Executive Order in 1935. The objective of our research is to develop a relativity inexpensive procedure to inventory and characterize abandoned U mines in the state using the Lucky Don and Little Davie U mines as case studies. U production at the Lucky Don and Little Davie mines (Chupadero district, Socorro County) occurred 1956-1959 and 1968-1969 from several adits. Hazard ranking of mine openings and features, using BLM ranking methodology will be utilized for most sites. Also we want to suggest remedial activities that would manage or mitigate dangers to the environment and public health, while taking into consideration historical, cultural and wildlife issues and mineral resource potential.

3:25 pm

Geomorphic and Biotic Controls on the Aeolian Transport of Uranium-Bearing Dust

R. Brown[1], D. Cadol[2] and B. Frey[2]; [1]Earth and Environmental Science, New Mwxico Tech, Socorro, NM and [2]New Mexico Institute of Mining and Technology, Socorro, NM

Mines pose risks to the environment and human health. Uranium contamination of water and soil have been studied, but few studies have investigated dust transport of U. At the Jackpile Mine, Laguna Pueblo, NM, 15 sets of dust traps were installed at various heights. Some traps are within the pit; others are as far as 4 km away[BF1]. Soil samples were collected. Samples were acid digested, and U was analyzed by ICPMS. We examined the correlation between dust and soil U content to evaluate soil contamination as an indicator of airborne contamination, while exploring the source relationship between dust and soil U. Results show that surface U varies across the landscape. Distance from the pit shows no correlation with U. Other factors control accumulation, such as vegetation height and density and topography, which are known to have a significant impact on wind speeds, soil erosion and dust deposition. Our site has over 150 m of relief that leads to a range of wind speeds between sites. The soil U content was compared to site elevation and vegetation height. Evaluation suggests that elevation and vegetation height may impact local erosion and deposition of U contamination.

3:45 pm 17-086

Mining at the Waste Isolation Pilot Plant

Z. Hyder and A. Urquidez; Mining, Missouri S&T, Rolla, MO

The Waste Isolation Pilot Plant (WIPP) is owned and operated by the U.S. Department of Energy. In addition, the WIPP is co-operated by the Management and Operating Contractor, Nuclear Waste Partnership LLC. The WIPP was designed for the permanent disposal of transuranic (TRU) radioactive waste and TRU-mixed radioactive waste resulting from the United States of America's nuclear defense programs. Transuranic radioactive waste destined for the WIPP is mostly comprised of contaminated tools, clothing, and other contaminated materials. The WIPP is a unique facility because the ore that is extracted from the mine is not used for profit; therefore, it is not a production mine from a conventional mining perspective. This paper provides a detailed discussion of mining plans and operations as well as safety and environmental considerations of this project.

4:05 pm

Leachability of Primary and Secondary Uranium Minerals

A. Pearce and I. Walder; Earth and Environmental Science, New Mexico Institute of Mining and Technology, Socorro, NM

Improved exploitation of the remaining uranium (U) in the Grants Mineral District, NM hinges on the development of a mineral-element speciation determination method. Understanding the mobility and leachability of U in mine wastes and ores has importance in both industrial and environmental applications. To this end, we evaluated the applicability of a previously established method for copper mine waste via sequential chemical extraction: deionized water, NH4-acetate, NH4-oxalate, H2O2 with carbonic acid, a combination of KClO3 and HCl followed by boiling in HNO3, and a four-acid digestion (HNO3, HF, HClO4, HCl) on U ores and mine waste.

MONDAY, FEBRUARY 20

AFTERNOON

2:00 pm Room 104

Environmental: Sustainable Development

Chairs: *S. Fecht, Ramboll ENVIRON, Westford, MA*
L. Wrong, Lundin Mining, Toronto, ON, Canada

2:00 pm

Introduction

2:05 pm

A Stepped Approach to Integrating Renewable Energy into Mining Operations

S. Tampke; Black & Veatch, Denver, CO

Mining requires significant amounts of reliable electricity to perform the necessary operations. In most cases, mining operations are highly mechanical and vary depending upon location and type of mining being conducted. As operators seek an assurance of electricity pricing going forward and work toward sustainability goals that seek to reduce the use of fossil fuels, exploring renewable energy generation has recently garnered more interest. While predictable, renewable energy generation is commonly fueled by variable resources, such as the sun and wind. Understanding the complexities of assessing, designing, managing, specifying, procuring, constructing, and integrating these resources with industries to provide the desired power requirements is no simple task. During this meeting we intend to facilitate an interactive environment where we will present the state of renewable energy (past, present, and future), invite discussion of how the mining industry might introduce RE into their electrical supply needs, and how Black&Veatch's global experience can be leveraged to assist energy users in making decisions that fit their use profiles and corporate sustainability goals.

2:25 pm 17-042

Digging for Survival: Female Participation in Artisanal and Small-Scale Mining in the Tarkwa Mining Area of Ghana

K. Bansah[2], N. Dumakor-Dupey[1] and G. Barnes-Sakyi-Addo[3]; [1]Mining Engineering, University of Mines and Technology, Tarkwa, Ghana; [2]Missouri University of Science and Technology, Rolla, MO and [3]Georgette Barnes Limited, Accra, Ghana

Artisanal and small-scale mining (ASM) occurs in many countries around the world, and provides a source of livelihood to many impoverished local people in areas where it occurs. This paper reports the role of female participants and reasons why they engage in ASM. Field visits were made to 12 ASM sites located in the Tarkwa Mining District of Ghana to conduct interviews with male diggers and female participants. It was observed that over 100 women between the ages of 18 and 50 participate in ASM for survival. They engage in ASM largely because they have no alternative employable skills and income sources. These female participants depend on ASM to sustain the lives of their dependents.

2:45 pm 17-075
Index of Nature Friendly Sustainability (NFS) in Mining
M. Javier; EnviroMINE, Denver, CO

Mining is the main activity that supports civilization. Actual mining presents contradictory concepts to health of planet. Its business model is linear, fragmented &characterized by inefficiencies in the utilization of water, energy &mineral resources which generate unlimited waste &pollution. Before mining, it is critical to determine vulnerability of ecosystem &after mining is also critical to determine depletion of nature. Attending to these vital matters will require quantifying &measuring them. Purpose of study is to provide &establish the metric to assess performance &manage a sustainable future for our existence &that of our planet. Index is defined to measure & control NFS based on understanding nature, it will determine condition of nature constructed on the measurement of physical chemical &biological equilibrium. Proposing a new mindset in mine design to satisfy nature's needs would be to offer same opportunities to future generations. Hence, sustainability is synonymous of equilibrium under limited ecosystem. Nature is interconnected. Finally, index of NFS is readable, standardized &relevant to keep nature's needs in equilibrium. NFS index is next metric for humanity.

3:05 pm
Towards Achieving a Sustainable Community to Meet Your Closure Goals.
K. Ashenbrenner and G. Burt; ERM, Minneapolis, MN

ERM research shows that over 50% of resource development projects are delayed, with stakeholder opposition contributing up to 52% of those delays. Just as social risk management is a key determinant of project success, it is equally important towards the end of a project lifecycle in achieving your closure goals. Closure carries implications for a community's economy, workforce, infrastructure needs, land values and site re-purposing and, as such, community stakeholders often focus on the non-technical aspects of closure. Companies on the other hand often focus their closure planning efforts to meeting environmental and technical requirements identified by regulators. To minimize the socio-economic impacts of closure, and to ensure a shared vision for regional or community economic transition and development, a strategic and inclusive approach is needed. This paper will share knowledge on the integration of social planning into your mine closure strategy and plan. We will share learnings from a closure process in which a diverse group of community leaders came to agree on specific actions to support economic diversification, knowing they would face closure in a 5-year timeframe.

3:25 pm
Holistic Management of Water at Mine Sites
S. Truby and D. Gibson; Black & Veatch, Denver, CO

Climate change is having an increasing impact on mine sites. Regional droughts have resulted in temporary plant closures, water quality issues, and difficulty meeting downstream release requirements. In other areas above average rainfall has resulted in excess water being stored, complicating facility management and compliance, at times resulting in the release of contact water to the environment, and potentially compromising facility safety. Black & Veatch has developed proven pro-active water management strategies. This includes audits to identify risks, water balance modeling to assess the risk of shortages or surpluses, and developing strategies to manage risks before they become problems. Due to diverse capabilities we are able to adopt a holistic risk management strategy. This can include developing strategies to release excess water, manage non-contact water, manage water quality, increase plant efficiency, and improve water supply. The presentation will review some of the issues that are being experienced at mines, and how they can be pro-actively managed using Black & Veatch's diverse expertise.

3:45 pm

Sustainable Development with Sense and Sensibility: Shared Value and Stakeholder Participation in a Complex Environment

C. Eddine; Public Admin, University of Victoria, Vancouver, BC, Canada

Can sustainable development and shared value be achieved with proper engagement? There is an expectation that mineral exploration companies adopt a shared-value approach to maximize local impact towards integrated sustainable development and social well-being. In addition, there is a demand for the sector to embrace and live by a triple bottom line framework, aligning financial accomplishment with environmental respect and contribution to social development. Good governance is the epitome of sustainable development. It encompasses informed and organized participation within a fair framework (rule of law) that provides accessible information (transparency) and a clear and reasonable timeframe (responsiveness), leading to a mediation of different interests towards a broad and long-term perspective that finally results in sustainable development (consensus). Accountability is a key condition for good governance. Sustainability requires a strategic participatory approach through multi-stakeholder involvement and can only be achieved with a holistic approach that integrates social, economic and environmental values.

4:05 pm

Running with Scissors; How to Avoid Unforced Errors Prior and During the Permitting Process: Setting Yourself up to Succeed

C. Hopkins; Principal, River Landing Solutions LLC, Franklin, TN

Most mining companies conduct endless test drilling, environmental studies, economic studies, but they either forget or do not attach as much importance to the political aspects of the application This session will focus on identifying ways to anticipate political issues that may be facing an applicant. This interactive session will provide a dialogue on how to avoid "unforced errors" that can occur during the process. There is typically enough fodder for any opponents and enough stress on the applicant due to the opponents and finally enough pressure placed on the decision makers by the opponents without making mistakes that will only increase all of these. We will discuss the need to identify and provide vital information on the decision makers at every level, who and where your opposition is likely to come from and how to identify and mobilize supporters for an application that will counter the opponents. There is a need to put the application into perspective and create a campaign for the project in order reduce the chances of delay or defeat. We will discuss ways to work with the community and what gets the applicant the most return on their investments with the local community.

MONDAY, FEBRUARY 20

AFTERNOON

2:00 pm **Room 108**

Environmental: Water Treatment

Chairs: *D. Graves, TREC, Inc., Bozeman, MT*
I. Montero, BP Remediation Management, Houston, TX

2:00 pm

Introduction

2:05 pm

Major Contributors to Mine Water Treatment Design for Nonferrous Mines

A. Martin; Mining, Foth Infrastructure & Environment, LLC, De Pere, WI

Water management, use, and treatment are an important part of mine operations and closure. We will discuss the significant contributors to water treatment design: tailings facility design, waste characterization, ore processing and effluent characteristics, and discharge permit limits. Modeling the contributors must suffice for a project under development, however; operating mines have real data to optimize operations and refine model predictions. Ore processing and tailings geochemistry in particular drive the liberation of metals and the potential for acid mine drainage (ARD), affecting short- and long-term water treatment needs. That said, a rigorous waste characterization program provides value throughout mine life and in many Midwestern states is subject to regulatory requirements. We will discuss how an integrated approach to design, operations, closure, and the priority and variability of various contributors impact the ultimate water treatment design and operations and can significantly affect project economics.

2:25 pm

Two Years of Operational Experience of Centralized Mine Water Treatment Facility in West Virginia

S. Muddasani, K. Banerjee and K. Benson; Veolia water, Pittsburgh, PA

A centralized mine water treatment plant was built in 2011 in West Virginia to treat mine water collected from six different locations. The objective of this advanced water treatment system was to meet a strict regulatory limitation imposed by the West Virginia Department of Environmental Protection for chlorides discharged to surface water. The system is designed to treat a maximum flow of 5 million gallons per day of mine water. The mine water is treated using advanced treatment technology to produce clean water for reuse or discharge. The treatment process consists of aeration, softening, filtration, reverse osmosis (RO), RO reject softening, evaporation, crystallization, final effluent remineralization and sludge dewatering. The residuals from the treatment process, including softening sludge and mixed salt cake, are concentrated into a solid waste that is disposed in a landfill on site. Since no liquid waste leaves this facility, so this facility is called Zero Liquid Waste Facility. Our presentation will describe the various treatment steps and present two years of operational data.

2:45 pm
Mercury Removal from Tailings Water
S. Barton and S. Billin; Linkan Engineering, Elko, NV

Abstract: Due to the high toxicity of mercury, the regulatory compliance limits for discharge of treated waters is 2 parts per billion, implemented in order to safeguard the downstream natural ecosystems. In some gold processing circuits that have high levels of mercury in the ore, it can remain in aqueous solution after gold dissolution and removal. This presentation summarizes the challenges associated with treating water containing this problematic pollutant, as well as presents the results of a multi-faceted pilot test, designed to compare select mercury removal methods, that was performed at one such mine site. This evaluation involved the use of Granular Activated Carbon (GAC), a mercury-selective Ion Exchange (IX) media, and a chemical agent, sodium dithiocarbamate (NaDTC), which were tested to understand their effectiveness and 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, and the test data that suggested desorption of thallium from iron salt coagulants as a result of the sodium dithiocarbamate addition.

3:05 pm
Dissolved Silica Removal from RO Brine
J. Wheeler and S. Billin; Linkan Engineering, Elko, NV

The potential for silica scale is real and can be very detrimental to the health of any Reverse Osmosis (RO) system. Silica not only decreases performance, but can irreparably damage the surface of an RO membrane to the extent that replacement is the only remediation. The risk of silica fouling is especially high in systems that either reprocess or treat RO brine through multiple RO passes. Systems in remote areas where brine storage is limited and/or waste volumes must remain low are often known to operate this way. In situations like this, antiscalant is not enough and either pretreatment of silica or a different technology is required. This presentation will discuss the limitations of antiscalant and the equipment and adsorption options that are available to mitigate the risk of silica scale. It will also discuss a recent pond treatment application in which silica was sufficiently removed for RO processing.

3:25 pm
A Next-Generation Approach to Bioreactor Optimization for Selenium and Nitrate Treatment Using Microbial Community Profiling (MCP testing)
V. Friesen and M. Haakensen; Contango Strategies, Saskatoon, SK, Canada

Advances in microbial technologies in the past five years have revolutionized the understanding of how microbes affect mining processes, and improved accessibility of testing. Microbes are now known to impact a wide range of mining activities, including heap-leaching, bioreactors, acid rock drainage, and passive water treatment. Next-generation microbial community profiling (MCP) testing now enables effective decision making associated with activities that are impacted by microbes. This presentation will provide an introduction to the current state of technologies used to understand microbial biogeochemical processes as they relate to the mining sector (such as bioreactors). The application of microbial community profiling technologies will be presented in the context of a bioreactor case study, where systems were operated under different conditions for processes and cost optimization for treatment of nitrate and selenium.

3:45 pm
Heavy Metal Removal – Options and Performance
H. Tozer; Industrial Wastewater, Woodard & Curran Inc, Portland, ME

Mines have many options for removing heavy metals from the water they discharge. The optimal solution varies with the water matrix, metal concentrations, solids disposal options, and other permit requirements, such as whole effluent toxicity or chloride limits. This presentation explores several treatment options using the example of a base metal mine/mill in the U.S. The mining company needed to meet stringent limits for cadmium, copper, lead, and zinc at four mines/mills. The design team conducted extensive field investigation of different options. The influent metal concentrations varied widely from site to site, which required a flexible treatment process. The mine owner also wanted a system that was similar from site to site to facilitate maintenance and operations. The tests identified a treatment process of hydroxide and sulfide precipitation followed by ballasted sedimentation. The first plant went online in 2013 and the fourth began operating in 2016. The plants have consistently met their discharge limits, and the design and operations team has found ways to meet the treatment objectives while managing operating costs.

MONDAY, FEBRUARY 20
AFTERNOON

2:00 pm **Room 612**
Health & Safety: Metric-Driven Approaches to Implementing H&S Interventions: A Series of Case Studies

Chairs: *E. Haas, National Institute for Occupational Safety and Health, Pittsburgh, PA*
C. Smith

2:00 pm
Introduction

2:05 pm **17-001**
A Case Study Exploring Field Level Risk Assessments as a Leading Safety Indicator
E. Haas[1], B. Connor[1], R. Heiser[2] and J. Vendetti[2]; [1]Office of Mine Safety and Health Research, National Institute for Occupational Safety and Health, Pittsburgh, PA and [2]Solvay Soda Ash & Derivatives North America, Green River, WY

Health and safety indicators help minesites predict the likelihood of an event, advance initiatives that may control risks, and track progress. Although useful to encourage organizational entities to work together, executing such risk assessments comes with challenges. This paper focuses on one trona mine's experience in the development and implementation of a field level risk assessment (FLRA) program to help their workers understand and manage risk to an acceptable level. Through a transformational process of ongoing support and communication, Solvay Chemicals fostered a culture of trust and safety grounded in risk assessment, safety interactions, and hazard correction. The application of consistent tools was critical to create a participatory workforce that not only talks about safety, but actively identifies energies that contribute to hazards and potential incidents. Reflecting on their process of FLRA implementation, this paper provides examples of likely barriers sites may encounter when trying to improve safety culture and manage risks. However, the performance metrics as provided on these qualitative FLRA's are well worth the initial struggle to minimize incidents on site.

2:25 pm 17-100

Quantifying and Monitoring Control Room Protection Factors Against Respirable Dust at an Underground Crusher Booth

J. Patts, A. Cecala, J. Rider, J. Organiscak and J. Zimmer; Pittsburgh Mining Research Division, National Institute for Occupational Safety and Health, Pittsburgh, PA

NIOSH recently completed a 15-month study at an underground limestone mine crusher booth which evaluated three research parameters: 1) the effectiveness of a single filter filtration and pressurization system for improving the air quality inside the operator booth, 2) evaluating and comparing the effectiveness of HEPA vs MERV 16 quality filters in the system, and 3) evaluating and comparing the use of three different pressure monitoring devices as a method of determining the performance of the filtration and pressurization system over time. The protection factor was quantified on a monthly basis using particle counters in the respirable range (1 – 10 um), and gravimetric dust samples were gathered at the beginning and end of the overall study. Under static conditions the single filter filtration unit installed offered a protection factor between 25 and 244, depending on the filter type and loading condition. The particle counting analysis shows that the MERV 16 filter offers a protection factor greater than 4 times that of the HEPA filter when evaluated over 60 minutes. The booth pressure monitors provided data that proved to be a valid indicator of system performance over time.

2:45 pm 17-106

Research of the Injury Rates in Selected Mining Sectors and the Economic Benefits of Mine Safety Improvements

C. Fuellenbach[1], J. Brune[2] and H. Mischo[1]; [1]Technical University Bergakademie Freiberg, Freiberg, Germany and [2]Colorado School of Mines, Golden, CO

Occupational safety and health plays an important role in the mining industry. An example for a safety improvement program in Germany is the "Vision Zero" program developed by the German professional association for the raw materials and chemical industries (BG RCI). Researchers at the Colorado School of Mines have investigated the correlation between safety performance and profitability in several mining companies. The goal of this research was to use engineering and economic methods to determine whether mines with lower accident frequencies and severity rates are also more productive and profitable operations. The research aims to quantify economic benefits of safety improvements in the German mining industry, with special regards to salt and potash and aggregates mining. The research focuses on the evaluation of incident rates across the last decades and its correlation to business numbers like profit and productivity. Another aspect studied is the comparison of incidence rates between the western and eastern States of Germany as well as the dependence of the injury rates from the enterprise size.

3:05 pm
Driving Leadership Interventions Using Metrics and the Positive 'Name and Shame' Methodology - Case Study: Asahi Refining US and Canada
M. Routledge; H&S Division Board, Park City, UT

Using simple metrics and displaying results of performance, Asahi Refining created a "Visible Safety Culture' that drove significant risk reduction across the operations. Setting targets for all employees from the operators through to the president and using mobile technology for recording field based safety interventions, the organization held each other accountable for proactively looking for and addressing hazards that may cause injury or fatality. In measuring the performance of each employee equally and following up on expectations using lean boards and a web based portal, the whole team through a positive 'name and shame' process, were held accountable to take action. The visibility of risk across the busniess gave the senior team the information needed to prioritize resources and focus them on both high frequency injury mechanisms and more importantly low frequency high consequence events that could cause fatality. After 1 year of using the methodology, Asahi Refining has removed significant fatal risks from the business and achieved an 80% reduction in all injury rates.

MONDAY, FEBRUARY 20
AFTERNOON

2:00 pm **Room 610**
Health & Safety: Technology Development, Adaptation, and Integration to Address H&S Challenges

Chairs: *M. Routledge, H&S Division Board*
E. Clausen, TU Clausthal, Clausthal-Zellerfeld, Germany

2:00 pm
Introduction

2:05 pm
Learning from the Manefay Highwall Failure
B. Ross; 90 Degree Consulting LLC, Tucson, AZ

The Manefay highwall failure at Rio Tinto Kennecott's Bingham Canyon Mine was significantly larger and had a very different failure mechanism than any failure the mine had experienced in its 107-year history. This failure forced the mine personnel to look at potential highwall failures differently that it had in the past. This paper, which is based on the new book, Rising to the Occasion – Lessons from the Bingham Canyon Manefay Slide describes how the knowledge gained from the Manefay was used to identify and prevent a second potential failure that could have been even more devastating than the Manefay itself.

2:25 pm

Tracking the Leading Indicators by Utilizing Leadership Participation and Technology

J. Wickizer; Brahma Group Inc, Salt Lake City, UT

Safety and health statistics have been measured using negative outcomes determined by field worker experiences, incident and accident data as one example. The measurement criterion for field service worker performance is determined by expectations set by regulatory agencies, customer expectations and internal corporate management. What is the outcome if more proactive safety measures are implemented by management, requiring both field employees and management to be accountable for participation? Does this process of combined effort and accountability on behalf of management and field workers yield a more positive safety culture? For two and half years executive management participation was recorded on a daily basis with simple safety expectations, similar to those of field employees. Thousands of active efforts and example setting opportunities were tracked and identified. Executive leadership support and self-discipline as a tool to motivate field worker safety behavior was utilized and tracked. The results were critical in identifying the greater impact that Upper management can have on the safety culture of an organization when combined with the efforts of all employees.

2:45 pm

Impact of Aging on Performance of Impactor and Sharp-Cut Cyclone Size Selectors for DPM sampling

S. Gaillard and E. Sarver; Mining and Minerals Engineering, Virgina Tech, Blacksburg, VA

Diesel particulate matter (DPM) is an occupational health hazard in underground mining environments. DPM concentrations are generally determined by collecting filter samples for subsequent analysis by the NIOSH 5040 (or similar) standard method. Since DPM generally occurs in the submicron size range, a size selector is used during sampling to exclude larger particles that could complicate analysis. The SKC diesel particulate matter impactor (DPMI) is commonly used in conjunction with a Dorr-Oliver cyclone to exclude particles greater than about 0.8μm; and a sharp-cut cyclone (SCC), used alone, has recently been shown to perform comparably. DPMIs are single-use devices that become loaded over time, and replacement is recommend after about 8 hours of use; overloading can impact DPM measurements. SCCs can be used repeatedly, but they may require periodic cleaning to maintain desired performance. This study evaluates the effect of DPMI and SCC aging (i.e., gradual accumulation of particulates) on accuracy of DPM measurements in a real mine environment.

3:05 pm 17-053

Electromagnetic Interference with Proximity Detection Systems

J. Noll, R. Matetic, J. Li, J. Srednicki, C. Zhou, J. Ducarme and M. Reyes; NIOSH, Pittsburgh, Pa, United States Minor Outlying Islands

In April 2016, MSHA began requiring the use of continuous personal dust monitors (CPDM) to monitor and measure respirable coal dust exposures to underground miners. After its implementation, mine operators discovered that the CPDM caused malfunctions to proximity detection systems (PDS), thus exposing miners to striking and pinning from continuous mining machine. NIOSH was sought out by MSHA and the mining industry to determine the cause of the malfunction of the PDS. NIOSH investigated existing standards, developed test protocols, designed experiments, and conducted lab and field evaluations. The malfunctions were found to be caused from electromagnetic interference (EMI) from the CPDM. Results showed that there was interference negligible to the PDS at a separation distance between the CPDM and the miner wearable component of the PDS of at least 6 inches. In order to operate the CPDM and PDS simultaneously, the CPDM and miner wearable component currently need to be equal or greater than 6 inches from each other.

3:25 pm 17-076
Industrial Internet of Things (IIoT) Applications in Underground Coal Mines

C. Zhou, N. Damiano, B. Whisner and M. Reyes; NIOSH, Pittsburgh, PA

The industrial Internet of Things (IIOT), a concept that combines sensor networks and control systems, has been employed in several industries to improve productivity and safety. NIOSH researchers are investigating IIOT applications to identify challenges and potential solutions for transferability from other industries to mining. Specifically, NIOSH reviewed existing communications and tracking systems used in underground U.S. coal mines to determine capabilities to support IIOT networks. The results showed that about 40% of the installed post-accident communication systems in 2014 require minimal or no modification to support IIOT applications by providing internet access to underground coal mines. NIOSH researchers also developed an IIoT monitoring and control prototype system based on low cost circuit boards, to detect a door opening on a refuge alternative, activate fans located inside the Pittsburgh experimental mine and activate an alarm beacon on the surface. The results of this feasibility study can be used to explore IIOT applications in underground coal mines based on existing communications and tracking infrastructure.

3:45 pm 17-085
MINER Act Technology: Past, Present, and Future

D. Snyder, S. Moore and J. Burr; NIOSH, Pittsburgh, PA

The Mine Improvement and New Emergency Response Act of 2006 (MINER Act Public Law 109-206) was passed by Congress in response to three major underground coal mine accidents in the United States that claimed the lives of 19 miners. The Act resulted in substantial changes in the underground coal industry relative to the use of technology for mine escape, rescue, disaster response, and other areas where the lack of these technologies contributed to the fatalities caused by these disasters. This year marks the 10th anniversary of the MINER Act, which makes it an opportune time to reflect on the events that led to its passage, the changes that have been made since then, and the work that remains to be done. The last decade has demonstrated tremendous cooperative efforts between the mining operators, technology innovators, labor, NIOSH, and regulators, resulting in substantial improvement of the technologies used for escape and rescue and noteworthy progress towards meeting many of the goals of the MINER Act. This paper will review these accomplishments of the past, and the challenges of the future, relative to the MINER Act technology development objectives.

4:05 pm 17-030
Characteristics and Controlling Factors of the E-Field of Electrode-Based Through-the-Earth (TTE) Communication
L. Yan, C. Zhou and M. Reyes; CDC/NIOSH, Pittsburgh, PA

The MINER Act requires the installation of post-accident, two-way communications and electronic tracking systems for all coal mines. One communication system which can satisfy this requirement is an electrode-based, TTE communication system which sends its signal directly through the overburden of a mine. The performance of these types of systems relies on several controlling factors such as communication distance, conductivity of the ground and antenna alignment. In an effort to estimate attenuation through the earth, NIOSH researchers developed an analytic solution for the electrical field distribution of an electrode-based TTE communication system and validated it using field data measured at an operating coal mine. The results of the validation will be discussed in this paper. The validated model can be used to optimize the operating frequency, estimate the required transmitting current, choose appropriate TX/RX orientation, and predict the performance of an electrode-based TTE system at a coal mine.

MONDAY, FEBRUARY 20
AFTERNOON

2:00 pm **Room 110**
Industrial Minerals & Aggregates: Innovations in Agriculture

Chairs: *L. Moore, ArrMaz, Mulberry, FL*
P. Golbayani, Imerys, Kennesaw, GA

2:00 pm
Introduction

2:05 pm 17-071
Impact of Clay on Phosphate Beneficiation
L. Moore, G. Wang, R. Xiong, Z. Gu and S. Renslow; Mining, ArrMaz, Mulberry, FL

Clays are known to contribute to a wide range of mineral processing challenges. These challenges can haunt a plant from the pit, through the beneficiation plant and even to the tailings pond and process water. Each step that the clay is present can potentially experience significant and costly impacts to the process efficiencies. The effect of clay minerals on the performance of phosphate flotation was investigated. The investigation led to an understanding of the movement of clay through the beneficiation plant, the impact on reagent usage, and the overall flotation performance.

2:25 pm

Overview of Calcium Carbonate Applications in Agriculture

P. Golbayani; Carbonates, Imerys, Kennesaw, GA

Calcium carbonate use in agriculture is vast and varied. There are a variety of ground calcium carbonate products used in various agricultural applications, including a carrier for agricultural chemicals, a soil sweetener, crop UV protection, and mineral supplement for farm animals. In addition, agricultural lime is a mineral fertilizer used to neutralize and nourish the agricultural land. It corrects soil acidity and pH levels by neutralizing the acids in soils so that the micro-organisms can thrive break down plant and animal residues and free the elements required for healthy growth of the land. This is vital to maximizing crop yield, animal grazing, and good quality silage/hay. In this study, we provide the overview of calcium carbonate application in the agricultural industry.

2:45 pm

Utilization of Steel Furnace Slag in Environmental Remediation

J. Yzenas; Edw. C. Levy Co., Valparaiso, IN

While Blast Furnace Slag (Iron) have been utilized in many aggregate applications over the years, Steel Slag is just starting to come into its own. One of the more interesting applications for steel furnace slag is in environmental remediation. This is a somewhat non-traditional role for these materials, but it has seen acceptance worldwide. These applications have spanned over several areas such as heavy metals remediation, phosphorous remediation and neutralization of acid mine drainage. This presentation will cover the role the chemistry, mineralogy, and physical nature of these materials plays in their success.

3:05 pm

Improving the Process of Blending Consistent and Predictable Feed in the Nickel Smelting Process Using PGNAA Technology

A. Montera; SABIA, Inc., San Diego, CA

ABSTRACT The process of blending consistent and predictable feed for the roasters is critical to optimizing product quality and controlling production costs. To assist in this process, Online PGNAA Slurry Analyzers have been installed and evaluated at a Sudbury Ontario smelter. They are used to measure 100% of the full process stream to obtain elemental composition data in real time. This paper explains the application details at Sudbury and the benefits achieved from their Full Stream, Elemental Slurry Analyzers.

MONDAY, FEBRUARY 20
AFTERNOON

2:00 pm **Room 112**
Industrial Minerals & Aggregates: Mine Plan Optimization

Chairs: *E. Tarshizi, Michigan Technological University, Houghton, MI*
J. Zdunczyk, Pike Industries, Inc., Westbrook, ME

2:00 pm
Introduction

2:05 pm
Be Aware of Partial Passes
L. Tolley, J. Wientjes, R. Kafka and J. Mills; Application Engineering, Komatsu America Corp., Peoria, IL

As a leading manufacturer and supplier of large-scale mining equipment, Komatsu strives to offer exceptional support to its customers, including through application studies. The Komatsu America Corp. (KAC) Application Engineering group conducts mine site visits in hopes of optimizing production and reducing costs. Recently the group has been involved in multiple studies involving the effectiveness of partial passes. These analyses include the production impact of partial passes for a loader dependent versus truck dependent application. Information considered in these analyses include such parameters as fleet specifications, bucket size, bucket fill factor, cycle times, spot times, number of passes, loose density, etc. This paper will review the key processes and calculations incorporated in the productivity aspect of using partial passes. Effort will be made to convey these procedures both numerically and graphically in a concise step by step manner. The intent is to provide a conceptual understanding of appropriate scenarios to utilize partial passes and the possible negative impact partial passes can have on production.

2:25 pm **17-125**
Using a QSO Expert Model to generate Quarry Optimization Plan to Improve Operation at Holcim Limestone Quarry, Crystal River, Florida, USA
K. Boakye, T. Newman, M. Toelle and P. Bláha; Cement Manufacturing, LafargeHolcim, Crystal River, FL

This paper presents a quarry optimization plan using a block model and an in-house developed quarry scheduling and optimization software (QSO Expert) to help improve quarry operation at Crystal River. The Crystal River Quarry is an underwater quarrying operation that barges limestone via the Gulf of Mexico, as the main source of raw material to a cement plant in Theodore, Alabama. To improve the quarry operation, an evaluation was complet-

SME TECHNICAL PROGRAM: MONDAY

ed to optimize the quarry planning and extraction procedures of the quarry. In order to achieve this, additional exploration drilling campaign was implemented, a new block model was re-calculated and the latest version of QSO Expert software was used. The primary economic impact is a higher recovery of limestone reserves sustainability of resources, corresponding higher quarry life. Secondarily as the limestone is mined underwater, a reduction in moisture content is achieved with direct cost impact on limestone shipping. In addition, a considerable reduction in operational cost was achieved due to significant decrease in consumption of electrical energy, reduced dragline maintenance costs and reduced dragline movements within the operation.

2:45 pm

Pit Optimization & Optimal Waste Dumping in a Land Constraint Deposit

F. van Beuningen; Lhoist North America, Henderson, NV

How to optimize reserves in a land constraint deposit where dumping on potential reserves is inevitable? During this project the land configuration was a constraining factor, and the pit optimization process required an iterative approach in which the topography is changing after every run due to the fact that the waste dump is created on top of potential future ore reserves. Original Whittle pit shapes are not valid after the creation of these waste dumps and require an updated topography. A good understanding of the deposit – including a good knowledge of the areas which can be 'sacrificed' for waste storage – is required to locate the waste dumps in the best location. The potential re-handling of waste dumps in order to maximize NPV and ore utilization was an ongoing question during this project. This process required a high level of manual adjustments since not all steps can be automated by the software. The report shows the approach and corresponding benefit of including mining cost per location in the geological block model for a dipping deposit.

3:05 pm

Integrated Uncertainty and Risk-Informed Decision Making Framework: Using Key Risk Drivers for Optimizing the Mine Plan

P. Felli and V. Tenorio; Mining and Geological Engineering, University of Arizona, Tucson, AZ

In the process of developing a strategic mine plan for large-scale open pit mines during times of operation and financial uncertainty, an approach that combines systems engineering processes and decision theories which emphasize the proper use of risk analysis is required in order to achieve project success. This study is focused on providing an understanding of how uncertainty and risk are leveraged for effective strategic decision-making. The key assumption is that mine planning can be modelled as a complex distributed organization, where each model component has its own unique objectives. Full value is only realized when all objectives are met. Key risk drivers that have a profound interest on the success or failure of the project are identified and analyzed for each sub-unit. These are classified into focus areas, pertinent to strategic mine planning and design, namely block modeling, ultimate pit design, pit optimization, pushback design, production scheduling and optimization. Each of these groups is then analyzed based on six categories: objectives, preparation, execution, environment, resilience, and results.

MONDAY, FEBRUARY 20

AFTERNOON

2:00 pm **Room 502**

Mining & Exploration: Geology: Midwest Exploration

Chair: *L. Johnson, Big Leif Exploration*

2:00 pm

Introduction

2:05 pm

Lead Generation and Evaluation of Frac Sand Targets in the Midwestern US: a Geospatial Perspective

R. Bergmann and B. Lentz; Big Rock Exploration LLC, Minneapolis, MN

Industrial silica sand has been a strong topic of discussion over the last five years due to the emerging frac sand markets. In light of this, it is imperative to understand the distribution and potential of industrial sand production throughout the Midwestern U.S. This study focuses on modeling 5 years of data compilation and field work aimed at defining areas of high potential for future Tier 1 frac sand production. The study criteria include: scientific, geospatial, transportation, and socio-economic factors contributing to frac sand developments throughout MN and WI. The ability to spatially analyze massive amounts of data has developed new approaches to exploring and defining mineral resources. Various modeling techniques can be utilized to assess multiple forms of data layers supplying a singular thematic output. Using Fuzzy Logic modeling, we have generated mineralization potential models for various mineral commodities throughout North America. This presentation will highlight our methods, results, and applications of utilizing these modern techniques to generate and evaluate frac sand potential throughout WI.

2:25 pm

Using Public Data to Generate Exploration Targets in the Midwestern United States: a Minnesota Example

R. Murphy; Clay Exploration, Acme Brick Company, Denton, TX

Acme Brick Company manufactures fired clay brick for residential and commercial use. Various publicly available datasets are used within Acme Brick for generating exploration targets for the expansion of our clay reserves. A discussion of commonly used data and techniques is useful as is a concrete example of this process in action. Acme acquired the Ochs Brick Company in Springfield Minnesota in late 2008 and the Exploration Department was assigned the task of assessing raw material reserves for the new acquisition. Exploration for industrial minerals such as clay and aggregates in southern Minnesota is very challenging due to the geology of the region. With assistance from the Minnesota Natural Resources Research Institute and the Minnesota Geological Survey, Acme Exp was able to locate and secure suitable raw materials for the Ochs Plant.

2:45 pm

Enhanced Online Public Access to Minnesota Minerals and Geology Data Using ArcGIS Online Web Maps

K. Hanson; Lands and Minerals Division, Minnesota Department of Natural Resources, St. Paul, MN

The Minnesota Department of Natural Resources (DNR) uses Esri's ArcGIS Online to facilitate public access to GIS data through web map applications, which are replacing or supplementing printed maps and GIS data downloads as sources of geological and minerals data. One DNR web map application focuses on the potential for construction aggregate resources across the state. A second identifies the locations of exploratory boreholes and areas of metallic mineral exploration. Supplemental map layers, such as Minnesota Geological Survey's GIS data, add additional value to these web maps, which can be used by the public without need of GIS software.

3:05 pm

New Structural Theory Ignites Innovative Gold Exploration in the Black Hills, South Dakota

B. Lentz and R. Bergmann; F3 Gold, LLC, Minneapolis, MN

The Black Hills of South Dakota have a long history of economic gold production. The Homestake mine was the most prolific and produced over 40M oz of gold averaging 8.35 g/ton in its 100+ year history. It is considered to be one of the richest and largest iron-formation hosted gold mines on earth and to date, a comparable deposit of size and grade has yet been found within the Black Hills region. Recent academic studies propose a new structural model for the eastern Black Hills with striking comparisons to mineralizing structures present at Homestake. This modern theory combined with our extensive database and field work suggests numerous targets containing favorable geology, alteration, and structure to host another Homestake like deposit. F3 Gold, LLC, a privately held gold company, has completed years of research and exploration work in collaboration with numerous Universities and Big Rock Exploration, LLC, an exploration consulting company. The results of this study work are exhibited in this presentation and include; detailed geological mapping, geophysics, and geochemical sampling suggesting untapped potential for gold in the Black Hills of South Dakota.

3:25 pm

Geology, Ore Deposits, and the Mineral Potential of the Precambrian Rocks of Northern Minnesota

D. Peterson; Peterson Geoscience LLC, Duluth, MN

Precambrian terranes of northeastern Minnesota host numerous world-class ore deposits. Mesoproterozoic rocks of the Mid-Continent Rift contain both large tonnage disseminated Cu-Ni-PGE deposits in the Duluth Complex and a high-grade Ni-Cu-PGE deposit hosted in conduit-type settings. The sedimentary rocks of the Paleoproterozoic Animikie basin host the great iron deposits of the Mesabi Iron Range, and historically great massive hematite ores were mined from the Neoarchean Vermilion greenstone belt. In addition to discussing these known deposits, the talk will highlight recent geologic work on the mineral potential of other deposit types, including lode gold, Cu-Zn massive sulfides, titanium, graphite, and diamonds.

MONDAY, FEBRUARY 20

AFTERNOON

2:00 pm **Room 504**

Mining & Exploration: Geology: Mineral Evaluation

Chairs: *A. Samal, GeoGlobal LLC, Riverton, UT*
B. Atkinson, Denver, Colorado

2:00 pm

Introduction

2:05 pm

Economic Evaluation of Rare Earth Elements (REEs) in Alaskan Coals

R. Pothina, T. Gupta, T. Ghosh and R. GANGULI; Mining Engineering, University of Alaska Fairbanks, Fairbanks, AK

Alaska is endowed with rich mineral deposits that consist of potential strategic, critical, and rare earth elements. REEs play a critical role in national defense, aerospace, renewable energy, high-tech, health care and many other industries. Increasing demand for REE and critical minerals warrants the search for new resources, such as coal and its byproducts. Alaskan coal deposits are rich in REEs and comprises of both Light and Heavy REEs. However, the economic viability and feasibility of Alaskan coal deposits as a secondary source of REEs needed to be investigated. The authors conducted economic analyses on certain Alaska coals for their economic viability. Two Alaskan coals (samples) from Wishbone Hill and Healy were successfully analyzed in the past, for the presence of REEs. Important characteristics of these REEs like density and concentration were also investigated through size analysis, float-sink tests, and magnetic separation. The authors conducted a feasibility study, cost-benefit analysis, cash-flow analysis along with establishment of pricing and marketing strategies. The results were subsequently compared with emerging pricing models like 'micro economic pricing'.

2:25 pm

Resource and Reserve Evaluation Factors for Lithium Brines

T. Cluff; WSP | Parsons Brinckerhoff, Reno, NV

Exploration for lithium (Li) resources in brine groundwater has jumped in recent years to meet anticipated demand. Unlike hard rock resources, evaluating a brine resource and converting to a reserve statement entail unique considerations pertaining to brine flow and capture. This difference between hard rock and fluid ore requires additional guidance for mineral resource statements to meet SEDAR 43-101standards. Li brine resources are controlled by the host aquifer's characteristics and require thorough characterization of hydrogeologic properties, the Li resource, and provenance. Key hydrogeologic parameters like specific yield, aquifer thickness, heterogeneity, Li grade, ion-exchange, and groundwater budget control the Resource evaluation. Conversion of Resources to Reserves must be evaluated in the context of fluid flow dynamics and brine extractability. This paper identifies hydrogeologic parameters, describes industry standard evaluation methods, and develops the framework to convert Resources to Reserves. Evaluation methods that could affect Reserve estimates, such as dilution, in-situ recovery, well field design, chemical transport, and processing controls are considered.

2:45 pm

Integrating Artificial Neural Networks and Geostatistics for Optimum 3D Geological Block Modeling in Mineral Reserve Estimation: a Case Study

A. Jalloh; Kyushu University, Fukuoka, Japan

In this research, a method called ANNMG is presented to integrate Artificial Neural Networks and Geostatistics for optimum mineral reserve evaluation. The word ANNMG simply means Artificial Neural Network Model integrated with Geostatiscs. In this procedure, the Artificial Neural Network was trained, tested and validated using assay values obtained from exploratory drillholes. Next, the validated model was used to generalize mineral grades at known and unknown sampled locations inside the drilling region respectively. Finally, the reproduced and generalized assay values were combined and fed to geostatistics in order to develop a geological 3D block model. The regression analysis revealed that the predicted sample grades were in close proximity to the actual sample grades. The generalized grades from the ANNMG show that this process could be used to complement exploration activities thereby reducing drilling requirement. It could also be an effective mineral reserve evaluation method that could produce optimum block model for mine design.

3:05 pm

Identifying Oppertunities for Selective Mining in Open Pit Bulk Mining Operations: a Case Study from Cortez Hills Open Pit

J. Baar, M. McMullen and G. Kurz; Technical Services, Barrick Gold Cortez, Elko, NV

Barrick's Cortez Hills Open Pit recently encountered a previously unidentifed, isolated high grade ore zone in the middle of their active open pit operation. This narrow and steeply dipping ore zone was located in an area designed for Life of Mine ramps. As a bulk mining gold operation, the narrow ore zone presented previously unencountered issues with extraction. The orientation and constrained nature of the the ore zone required high definition for minimal dilution. The challenge was mitigated with a series of reverse circulation (RC) drilling as well as selective infill blast hole campaigns.

3:25 pm

Risk Analyses in a Mineral Resource Estimate: Useful Technical Details for Project Financing

A. Samal; GeoGlobal LLC, Riverton, UT

Use of single estimate of tonnage and associated grade of the mineral resource, at a predefined (or calculated) cutoff grade is common practice in the mining industry. Key technical risks and opportunities associated with estimated resource can be translated into reduction or, an increase of tonnages and improvement or decline of quality of the mineable mineral resources. The resource estimation techniques should be dictated by the style of mineralization. Often non-linear estimation techniques are powerful in predicting potential risks and opportunities in mineral resource estimates. Using anonymous examples, this presentation will discuss how an investor can gain very useful regarding risks and opportunities attributed to the geological nature of the mineralization and the procedures followed in the assessment of mineral resources for investment related decision making.

MONDAY, FEBRUARY 20

AFTERNOON

2:00 pm Room 506

Mining & Exploration: Management: Mine Management

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

2:00 pm
Introduction

2:05 pm 17-078
Luck & Skill: Black Swans & Machiavelli's Ideas on Power, Fortune, Virtù

T. Camm; Montana Tech, Butte, MT

We hear all the time about the value of hard work and perseverance, and the part they play in the professional life of successful people. What we do not hear so much about are the many professionals who work hard and persevere, yet never seem to quite reach the level of success they aim for. Some current authors are beginning to give more attention to the part luck/black swans/tipping points play in success. This is not a new phenomenon, Machiavelli had a lot to say about it back in the Renaissance. So how can knowledge of this dynamic help in a modern organization?

2:25 pm 17-080
Managing Engineering Talent: Unique Challenges to Optimize the Best and Brightest

T. Camm[1] and J. Johnson[2]; [1]Montana Tech, Butte, MT and [2]Mining Engineering, University of Utah, Salt Lake City, UT

Most engineers are bright, hard-working, reliable, and prefer to avoid conflict. An engineering curriculum tends to self-select these characteristics. By most standards, you would expect workers exhibiting these traits to require minimal supervision. But is this true? Is this how most current engineering managers lead? Looking at some current theories on leadership combined with personal anecdotes, this presentation will look at some common misconceptions about leading engineers.

2:45 pm
Improving Mine Performance through Communication
F. Arboleda; Research, acQuire Technology Solutions, Applecross, WA, Australia

A critical component to optimize performance and productivity at mine operations is to ensure material is routed correctly and efficiently through the core mine production activities of drilling, blasting and grade control. Multiple teams are involved in the mining extraction process. These teams are all under time pressure to perform. One of the root causes of this pressure is the dependencies between the teams. They do not operate in isolation, but are a link in a chain depending on the outcomes of each activity. It is essential communication is efficient so tasks can be completed according to the production schedule. With different systems used for the parts of a common goal, supervisors and managers lack visibility of the process. This makes it difficult to identify process improvement opportunities. The proposed streamlined communication solution consolidates all data and activities resulting in improved cooperation between mine production teams. This situation raises the confidence and efficiency of material routing decisions. Having everyone collaborating off the same trusted data, helps teams identify with common goals and find business improvement opportunities as they appear

3:05 pm
Effects of the Blast Induced Vibrations on Mine Planning According to Relocation of Existing Administrative Buildings, a Case Study
J. Sattarvand[1] and M. Baseri[2]; [1]Mining and Metallurgical Engineering, University of Nevada Reno, Reno, NV and [2]Mining Eng., Sahand University, Tabriz, Iran (the Islamic Republic of)

The study conducted to determine the best site specific vibration propagation law through numerous measured blast events at a large open pit copper mine. Severe topographical condition of the mine site along with the low prices of the copper during start up time of the mine led to a mine facilities layout selection that was quite close to the open pit and had to be replaced after market recovery and expansion of the ultimate pit limits. Study revealed that under current blasting condition and production plan, mine facilities will be highly damaged after less than two years that is a very short notice for establishment of the new site. However, required modifications in blasting technique and production scheduling to differ repositioning long enough are studied and offered.

3:25 pm
Leadership During Times of Crisis
B. Ross; 90 Degree Consulting LLC, Tucson, AZ

Leadership is always critical for organizations – but especially when that organization is in a crisis situation. This paper, which is based on the new book, Rising to the Occasion – Lessons from the Bingham Canyon Manefay Slide, describes some of the methods used by the leadership at Rio Tinto Kennecott's Bingham Canyon Mine to prepare for and recover from the largest mining landslide in history. These methods were essential in keeping people safe and returning the mine to production much faster than just about anyone thought possible – and are applicable to everyday operations.

3:45 pm
Mining's Digital Communications: Utilizing Web Tools and Data for Enhanced Value
T. Hall; Clear Creek Digital, LLC, Wheat Ridge, CO

Global connectivity provides many platforms for information, dialogue and content sharing extending well beyond a corporate website. Unfortunately, web sites and social media frequently curate inaccurate information seldom policed. A digital reputation and footprint online is becoming more critical for every business. Mining companies are no exception. An inactive presence through communication platforms will not strengthen a company's reputation. Online opinions and falsehoods will continue to be shared with or without a mining company's engagement. These dialogues, however, should be seen more of an opportunity rather than a hindrance. This presentation, organized into 5 topics, will provide introductions to finding the value these platforms offer in stakeholder data and engagement. Topics include: 1. Understand Your Digital Footprint and Reputation, 2. Web Analytics and Social Media Data, 3. Social Listening and Engaging (Even through negative dialogue), 4. The User Experience, and 5. Importance of Being Mobile Responsive. Clear Creek Digital will offer examples of both major mining companies and mid-caps utilizing digital communication tools for their projects.

MONDAY, FEBRUARY 20
AFTERNOON

2:00 pm **Room 503**
Mining & Exploration: Operations: Mine Planning and Development for Operational Excellence
Sponsored by ARCADIS

Chair: *R. Rojas, Freeport McMoRan, Tucson, AZ*

2:00 pm
Introduction

2:05 pm **17-067**
Fundamental Error Estimation and Accounting in the Blasthole Sampling Protocol at a Copper Mine
R. Ganguli[1], A. Chieregati[2] and A. Purvee[3]; [1]University of Alaska Fairbanks, Fairbanks, AK; [2]University of Sao Paulo, Sao Paulo, Brazil and [3]Mongolian University of Science and Technology, Ulaanbaatar, Mongolia

A heterogeneity study was conducted at Erdenet Copper Mine in Erdenet, Mongolia, to determine the fundamental sampling error (FSE) associated with blasthole sampling. Using a custom designed sector sampler, six large blasthole samples were collected to perform the test that was developed by Pierre Gy to estimate the constitutional heterogeneity factor for several types of ore. The study investigated the entire sampling protocol, from mine site to analytical laboratory, and quantified the contributions to FSE of the various

SME TECHNICAL PROGRAM: MONDAY

stages of sampling and analysis. The total relative standard deviation (RSD) of sampling error was determined to be 32% and 49.4% for copper and molybdenum respectively. A classical statistics analysis conducted on the data confirmed the level of RSD. About 95% of the sampling error was produced from one step in the sampling protocol: when the 1kg sample was reduced to 50g sample for analysis. Therefore, it was recommended that the 1 kg sample be ground before it is split for analysis, reducing the FSE to 7.9% and 17% for copper and molybdenum respectively.

2:25 pm

Industrial Strength Mine Haulage and Extraction Simulation: a Key Towards Operational Excellence

H. Askari-Nasab[1], M. Tabesh[2] and S. Upadhyay[2]; [1]OpitTek Mining Consulting / University of Alberta, Edmonton, AB, Canada and [2]OptiTek Mining Consulting Ltd, Edmonton, AB, Canada

A mine and extraction simulation operational planning tool with Excel input/output interface and automated reporting has been developed, validated and used as part of the short-range planning of a large-scale oil sands open pit operation in Canada. The simulation tool takes the mine production schedule as an input and imitates the truck-shovel haulage-systems and its interaction with the extraction plant including crushers and downstream assets. The simulation tool accurately reported the major system's KPIs at 95% level of statistical confidence within 3% accuracy of the historical dispatch data for the project. Major KPIs reported by the automated output reporting system are: ore and waste production, queue time, spot time, load time, dipper tonnage, haul time, dump time, truck speeds, backup time, loading cycle time, head grade, time and number of trucks in queue, and truck-and-shovel operational KPIs. The simulation tool gives the planner capability to assess the impact of changing operational scenarios such as stockpiling, different sizes of mixed-fleet trucks, and introduction of new haul-roads into to the mine plan. Normalized results of the project will be presented.

2:45 pm

Long-term Production Scheduling of Open Pit Mines through Imperialist Competitive Algorithm

J. Sattarvand[1] and M. Mokhtarian Asl[2]; [1]Mining and Metallurgical Engineering, University of Nevada Reno, Reno, NV and [2]Mining Eng., Sahand University of Technology, Tabriz, Iran (the Islamic Republic of)

Long-term production planning of an open-pit mine is the procedure during which the rock blocks are assigned to different production periods in a way that the highest net present value of the project achieved subject to operational constraints. The paper introduces a new meta-heuristic technique for this problem called Imperialist Competitive Algorithm (ICA) inspired by the socio-political process in imperialistic competition and construction of the colonies. It starts with an initial population of solutions, representing the nations and, according to the quality of objective function in each solution, a series of empires are built by designating some of the best countries as imperialists and the rest as colonies. Over the time, imperialists try to extend their features to the governing colonies; however, revolutions might happen in countries. Countries can also leave their empire to others if they see higher chance of promotion. The proposed open pit optimization algorithm presents new rules of the assimilation to the original process. Results from the application of the algorithm is studied and compared to that of mathematical programming on a real scale copper mine block model.

3:05 pm

Building a Stockpile Model and Integrating Systems for Modelling Gold Grade to Increase Confidence to Reduce the Risk Into the Short Term Mine Planning in Newmont Akyem Mine

B. Perez; Newmont Mining, Greenwood Village, CO

Newmont Akyem mine in Ghana is committed to optimizing results. A changing environment requires of a better understanding of the deposit and the gold contained in the ore. This allowed the mine planners to adjust and response to economic changes for Gold price. Newmont Akyem Mine has approximately 10 million tons of ore in the stockpiles. Mine planers were using average grade in all stockpiles. Data mining techniques were applied to extract several years of information to model with a more confident grade at the stockpile. A simulation of grade variation on the blend using the results of the produced stockpile model calculates the risk of assuming average grade in the stockpiles vs. the new model. This paper describes how the information in the operation database integrates with MineSight to create a stockpile model using the existing tools used for the ore control in Newmont Akyem mine. Stockpiles are the main component in the weekly production plans for the mine to achieve production goals. The stockpiles management is also crucial to response to changes in cutoff grades, sequencing, adjustment per contingency, gold price and reduction in cost in the Short Term Planning.

3:25 pm

Blending Confidence Classes from Resource/Reserve Reporting Standards to Control Production Performance – a Full Case Optimization Study in a Gold Deposit

M. Bijmolt[1], J. Benndorf[2] and M. Godoy[3]; [1]TU Delft - Resource Engineering, Student, DELFT, Netherlands; [2]Professor, Freiberg, Germany and [3]Group Executive, Resource Modelling - Newmont, Denver, CO

Meeting short-term production targets is desired by many companies, since this enables to fine-tune the processing operation, meet budget plans and obey contract requirements. Recently stochastic optimization solutions have been developed requiring geostatistical simulations as input. The significant value added has been demonstrated, however, an operational implementation of such approaches for day-to-day use is complex and seems currently difficult as it requires expert knowledge and extensive computational capacity. To control short-term deviations from production targets, a new short-term scheduler is presented that optimizes block-blends for target ratios of Geological Confidence Classes. This rather simple approach uses typical uncertainty information available in a mine, namely classifications of resource or grade control blocks according to international reporting standards with its associated levels of confidence. The optimization approach will be presented, including a method to define critical target ratios of measured to indicated resource blocks. The ability of the optimizer to control target deviations is demonstrated in a full scale case study in a gold deposit.

3:45 pm

Extreme Redesign of the Mine Plan and Sequencing as a Safety Measure for Stability of Infrastructure and Ore Extraction of the Turf Deposit at Newmont's Leeville Underground Mine

W. Robertson and K. Geddes; Engineering, Newmont Mining Corp., Elko, NV

A full scale redesign of the mining method and sequence has been implemented at Newmont's Leeville Underground Mine as a safety measure to protect the recently completed #3 Shaft as well as all associated LOM and short term mining excavations. An increased understanding of the geologic and geotechnical environments in the north areas of the Turf deposit has forced an extreme shift in production potential and ground support requirements. Utilizing a site specific ground hazard model, numerical models, and an iterative cost analysis process, the northern zones of the Turf deposit have been redesigned to ensure safe and profitable production of the deposit.

4:05 pm

Haulage Calculations for Adjacent Pushbacks

J. Quispe[1], A. Moharana[2] and Z. Huang[2]; [1]Freeport-McMoRan Inc, Morenci Operations, Morenci, AZ and [2]Hexagon Mining, Tucson, AZ

One of the major components of Life-of-Mine plans for open pit mines is to calculate truck requirements, and several software packages are available to the Mine Engineer in order to automate this task. However, a recent application of Minesight Haulage ® put into closer examination the case when an open pit has a pair of adjacent pushbacks that are mined concurrently, and where the haul profile corresponding to one of them is being mined by the next pushback. This paper shows how to deal with this case, as the user needs to ensure that haulage calculations using Minesight Haulage® are taking into consideration the proper haul profile at any period.

MONDAY, FEBRUARY 20

AFTERNOON

2:00 pm Room 505

Mining & Exploration: Operations: New and Expansion Underground Operations Overview

Chair: *M. Tilley, Cementation USA Inc, Sandy, UT*

2:00 pm

Introduction

2:05 pm

Canyon – Development of a High Grade Uranium Mine in Arizona

T. White, Lakewood, CO

The Canyon Mine Project is a high-grade uranium breccia pipe deposit that is orientated vertically from 900 to 2,000 feet below the surface. The Project is located 55 miles northwest of Flagstaff, Arizona and 7.5 miles south of the Grand Canyon National Park boundary. The deposit will be accessed by a rectangular 3-compartment shaft that is being sunk conventionally by Energy Fuels crews. The deposit is expected to be extracted utilizing a combination of longhole open stoping and shrinkage stoping methods. The presentation will provide a mine development update, discussion of the mine plan, project challenges, and lessons learned. The project challenges include intense regulatory scrutiny due to the project location, fast tracked underground delineation drilling and orebody modelling to keep pace with mine development, and development cost reductions during a period of low uranium prices.

2:25 pm
Roadheader Use for Development Tunneling in Nevada
X. Naeger; Cortez Hills, Barrick Gold, Crescent Valley, NV

Barrick Cortez Underground is currently undergoing its Lower Zone Expansion project. The project includes underground maintenance shop, batch and shotcrete plant, loading bins and conveyor belt to deliver material to the surface. As part of this project, two parallel declines will be mined to support the conveyor and secondary traffic. The declines will be driven via use of a Sandvik MH620 Roadheader. This presentation will cover an overview of the expansion and focus on challenges and advantages with regards to roadheader use as well as data acquired from the first months of the project.

2:45 pm
Application of Virtual Reality in Mine Engineering and Construction
C. Vought and C. Haws; Engineering, Cementation USA, Sandy, UT

The purpose of this paper is to document the investigation and application of Virtual Reality (VR) hardware and software within the mining and minerals industry. VR is an emerging technology primarily focused on gaming that has tremendous potential as an advantageous tool for the Architectural, Engineering and Construction (AEC) trades. By its very immersive nature, VR has potential to be a key tool to convey clear design intents and identify potential safety concerns in a true perspective experience. This paper will document not only the knowledge, hardware, and software requirements of applying VR to mine engineering and construction, but also firsthand experience in using Virtual Reality in the following real world applications: Infrastructure Design and Review (COMS) Virtual preconstruction services tool Risk analysis with first person presence Marketing to minerals project investors

3:05 pm
Lucky Friday Mine - Stepped Longwall Mining Method
W. Johnson; Technical Servces, Hecla Mining Lucky Friday Unit, Mullan, ID

The Lucky Friday Mine employs the mechanical cut and fill mining method, developed in the mid 1980's to address issues of deep mine induced seismicity. To better manage the reserve at great depths, a modification of the mining method has been proposed and aims to further reduce mining induced seismicity, improve ore face availability, and sublevel efficiency. The stepped longwall method moves the backfill cycle out of the critical path for ore production by adding stope access along strike. The method is planned to be implemented over the next two years as Lucky Friday commissions the new #4 shaft and expands to greater depths.

MONDAY, FEBRUARY 20

AFTERNOON

2:00 pm **Room 501**

Mining & Exploration: Technology Innovations in Surface Mining

Sponsored by KNS Communications

Chairs: *E. Fretheim, Freeport-McMoRan, Oro Valley, AZ*
H. Ednie, Global Mining Standards and Guidelines Group (GMSG)

2:00 pm

Introduction

2:05 pm

Getting Digital: How Barrick Cortez Embraces Digital Technology to Improve Safety and Efficiency

H. Dahlman; OP Tech Services, Barrick Cortez, Elko, NV

Mining is an age old practice with a virtually unchanging method: drill, blast, load haul. In a time of limitless access to technology and data collection, it is time to rebrand the industry. To harness new technologies to make mining the safest industry in the world while, achieving efficiencies that will drive costs down and revenue up. Barrick Cortez is entertaining existing technologies while also challenging our partners in innovation to provide out of the box solutions. Through a site wide initiative with inputs from every division, Barrick Cortez is marching forward in becoming the technological flagship for Barrick as a whole. Implementing safety technologies that will make Barrick Cortez the safest mine in the world and plan compliance technologies supplying real time data for optimal decision making. The sky is the limit as we work to find safety and efficiency solutions that will become the next standards in the mining industry.

2:25 pm

Optimum Dig Line Design for Open Pit Grade Control

E. Isaaks; Earth Sciences, Isaaks & Co., Emerald Hills, CA

Open pit grade control is a series of tasks beginning with blast design and drill, followed by the sampling and laboratory analysis of drill cuttings, the estimation of block grades, and finally dig line design. As the name suggests "grade control" is critical to ensuring mined material is sent to the correct destination. However, a number of challenges bedevil the various tasks. Careers have been made out of solving blast hole sampling and laboratory problems. Books have been written on how to best estimate ore control block grades. But relatively little attention has been paid to dig line design. Indeed, the manual contouring of block grades and sample assays with colored crayons appears to be the industry standard. As an alternative, it's very easy to show that a smart computer program designed to optimize dig line design will generally increase net revenue over manual designs by 2% to 7%. This is accomplished by minimizing the number of blocks sent to the wrong destination. An algorithm for the design of optimum dig lines constrained by a minimum mining width is presented together with examples from current mine operations.

2:45 pm

Optimizing Ore Diglines with Consideration for Dig Direction and Blast Movement in Surface Mines

W. Hunt[1], J. Loeb[1], A. Cervantes[2], J. Kalla[3], B. Hipwell[3] and J. Cooper[4]; [1]Blast Movement Technologies, Denver, CO; [2]Compania Minera Dolores, Chihuahua, Mexico; [3]Geology, Boliden Kevitsa, Petkula, Finland and [4]Anaconda Mining, Baie Verte, NL, Canada

In single-flitch surface mines, ore and waste boundaries are often designated by creation of 2D polygons. Optimizing the dig limits for these polygons through statistical and probabilistic methods is critical, but blast movement alters the shapes and locations of these polygons. Can a polygon created at mid-bench be projected to the surface with the same unavoidable dilution/ore loss that existed in the pre-blast state? Is there a better way of performing field ore control? To know the answer, the three-dimensional post-blast shape of the ore body must be known. In structurally controlled mines where the ore body is accurately defined, an opportunity exists to optimize the dig limits by evaluating the post-blast 3D shape of the ore body using Blast Movement Monitors (BMMs) at various depths. Here, a solution has been created to optimize the 2D digging polygons to increase recovery of the 3D post-blast ore body. The method and results are presented in use at Dolores silver mine, Kevitsa nickel-copper mine, and Pine Cove gold mine. The benefits are significant when compared with simply creating a polygon at mid-bench and ignoring the post-blast shape of the ore body.

3:05 pm

Improving Excavation Load Cycles through Technology

C. Orr; Modular Mining Systems, Inc., Tucson, AZ

The excavation load cycle in open-cut mining is central to efficient operations, making it a key target for optimization. However, optimizing this cycle poses many challenges and is often complex due to the numerous competing factors involved, including bench design, safety, truck spotting, truck and shovel size, operator skill levels, and single- or double-side loading. Effective optimization requires maximizing each segment of the load cycle while accounting for these factors. Traditionally, operations, engineering, safety, and training departments within an organization undertake the efforts to optimize excavation load cycles, often focusing on specific portions of the cycle, rather than the load cycle and its competing factors as a whole. This traditional method rarely yields sustainable outcomes. This paper will present newly-emerging technologies and processes that can account for all competing factors, allowing for a holistic approach to optimizing load cycles. Data will show that these new technologies can achieve a reduction of more than 30% in the load cycle, as well as improved predictability, aiding in improved planning and adherence to plan.

3:25 pm
A New Approach to Mine Management Systems Utilizing the Internet of Thing
M. Baker; CheckMark Consulting, Tucson, AZ

The Internet of Things (IoT) is a disruptive technology that has revolutionized the systems approach to solving problems in all industries. It refers to uniquely identifiable objects and their virtual representation on the internet. IoT applications consist of data capture, the reduction of the data into meaningful information and the process of acting on that information. Devices that gather data range from simple RFID tags to complex devices that incorporate multiple sensors and actuators including smart phones and tablets. Cloud based computing eliminates the need for local servers. Gamification is the incorporation of game elements, like rewards, to motivate people to achieve goals. Gamification minimizes the often overlooked change management efforts that have been the root cause for the failings of traditional technology-based systems. These new relatively low cost disruptive technologies have been combined to create a platform for the next generation of Fleet Management Systems. This presentation highlights one approach to effectively track and improve production, productivity and availability of fleets of equipment and operators for both open pit and underground operations.

3:45 pm
Developing a Global Vision of Autonomous Mining: Industry-Wide Collaboration to Enable an Innovative, Safe Future of Mining
A. Scott; Barrick, Toronto, ON, Canada

As mining companies continue to experience increased cost pressure from low commodity prices, there is a growing expectation within the industry for better adoption and use of technology to improve the efficiency and profitability of the operating model. While many other industries have benefited from the innovative use of automation and information, mining has continued to rely on a more manual, batch driven process. To support the next generation of mining, operators will need to integrate their production processes from mine to port, and optimize the end to end performance in support of a more continuous and predictable operating model. Through a series of 2016 workshops, a global vision of autonomous mining has been developed by GMSG. Key areas of focus within the vision include integrated operations, interoperability, the need for mining solutions to have an extendable architecture on which to build, and integration into manual systems. Agreement on a global industry vision of autonomous mining will act as a guiding framework for mine operators, OEMs, and technology developers, and provide a framework to enable a systemic approach to drive industry guidelines of the future.

4:05 pm
Adapting Open Pit Mining Optimisation Techniques to Design Martian Mining Method and Fleet for Water Extraction
C. Tapia Cortez[1], S. Saydam[1], R. Shishko[2], A. Dempster[3] and R. Fradet[2]; [1]Mining Engineering, UNSW, Sydney, NSW, Australia; [2]Caltech/NASA Jet Propulsion Laboratory, NASA, Pasadena, CA and [3]Australian Centre for Space Engineering Research, UNSW, Sydney, NSW, Australia

Efforts carried out by international space agencies such as NASA to expand exploration and research in the solar system have also expanded the frontiers of mineral resources exploration to asteroids, the Moon and Mars. Assuring the survival of human crews during extended missions is crucial for the success of Mars colonisation programs. As a result, in-situ resources utilisation of mineral is essential and water production the most. Mars mining activities should also face a number of uncertainties regarding mineral resources as well as technical and financial restrictions such as investment, production rate and fleet capacity. Adapting open pit mining and fleet dimensioning optimisation techniques provide an accurate framework to assess uncertainties of Martian mining operations, design extraction methods and associated fleets to support explorations crews and colonies in the red planet. This paper introduces the adaptation of terrestrial mining optimisation techniques to simulate, optimise and assess the performance of Martian mining operations in a comprehensive computational tool so-called Water Extraction Mars Mining Model (WEM^3).

MONDAY, FEBRUARY 20

AFTERNOON

2:00 pm **Room 703-709**

MPD: Plenary Session

Sponsored by Moly-Cop USA, LLC

Chairs: *C. Brierley, Colorado School of Mines, Golden, CO*
M. Moats, Colorado School of Mines, Golden, CO
D. Nagaraj, Cytec Solvay Group, Stamford, CT
E. Spiller, Colorado School of Mines, Golden, CO

Gaudin Lecturer: Gerald Luttrell

Title of Lecture: Industrial Applications of Advanced Process Engineering

Richards Lecturer: S A. Ravishankar

Title of Lecture: Pushing the Limits of Physical Separation and Processes with Chemistry

Wadsworth Lecturer: Fiona Doyle

Title of Lecture: Hydrometallurgy, Sustainability, and Economic Competitiveness – How Have the Decades Changed Our Thinking?

Presentation of Rong Yu Wan Ph.D. Dissertation Award

Award Recipient: Qingqing Huang

MONDAY, FEBRUARY 20

AFTERNOON

2:00 pm **Room 212**

Society of Mining Professors Session: Distance Education – Pitfalls and Opportunities

Chairs: *V. Kecojevic, West Virginia University, Morgantown, WV*
B. Hebblewhite, University of New South Wales, Sydney, NSW, Australia

2:00 pm

Introduction

2:05 pm 17-132
Diversity in Mining Engineering Faculty Worldwide: Data Collection, Analysis, and Visualization

E. Tarshizi[1], E. Sarver[2], R. Setterlind[1], Z. Scopa[2], R. Livernois[1] and L. Frost[2]; [1]Department of Geological and Mining Engineering and Sciences, Michigan Technological University, Houghton, MI and [2]Department of Mining & Minerals Engineering, Virginia Tech, Blacksburg, VA

The mines of the future will present a host of engineering challenges including needs for new technologies, systems integration with big data issues, increasingly complex environmental problems, and evolving demands regarding social responsibility. The mining engineers of the future must then have highly diverse skillsets, meshing traditional and contemporary competencies. How ready are the world's leading educational programs to meet these needs? Beginning with a search of the SOMP membership, we conducted an online survey to collect demographic data on over 700 mining faculty worldwide. Analysis of this rich dataset provides a glimpse into the current strengths and needs of mining programs. This work will summarize results and discuss the benefits of diverse faculty groups in terms of appointment types and levels, areas of expertise, gender, and cultural backgrounds.

2:25 pm
Society of Mining Professors Session: Distance Education – Pitfalls and Opportunities

B. Hebblewhite[2] and V. Kecojevic[1]; [1]Mining Engineering, West Virginia University, Morgantown, WV and [2]Mining Engineering, UNSW Australia, Sydney, NSW, Australia

This session is organized by the Society of Mining Professors. We focus on experiences in distance education – good, bad or indifferent, with the idea of stimulating a good discussion session.

2:45 pm
Practical Online Learning for Cross-Generational Skill Development

C. Johnson; Technical Services, Maptek, Lakewood, CO

Knowledge today flows to almost any location with a quick swipe across a smart phone or tablet. While millennial brains are hard-wired to learn from short bursts of information delivered in a world of distraction, older generations are wired to absorb information differently. This dichotomy of learners presents a unique challenge for instructional designers. In a society with so many distractions, opportunities, and obligations, classroom learning is an inconvenient option for most. In our fast-paced and demanding culture, learners are well-served by asynchronous or blended learning platforms. To meet the needs of all current and future industry professionals, learning must be easily accessible, user-friendly, and make the most efficient use of precious time. As instructional design professionals, we must incorporate multidisciplinary learning and cross-functional lessons to ensure learners grow into resourceful, and valuable employees. This discussion explores the philosophy of education behind one practical training model solution aimed at professionals who must acquire and immediately apply skills to unique industry challenges.

3:05 pm 17-057

Engineering Online: Program Development to Address the Educational Needs of the Mining Industry

D. Yokom and T. Katsabanis; Robert M. Buchan Department of Mining, Queen's University, Kingston, ON, Canada

The mining industry is facing a human resources challenge: a large percentage of the working population is set to retire in the next decade. Replacement has traditionally come from current mining programs; however, these programs have been declining in numbers, and those that remain face challenges such as fluctuating enrollments, and reduced budgets. Queen's University and Northern College have partnered to develop an innovative new program that offers online mining education to engineering technologists seeking to upgrade their skills and obtain a Bachelor's degree. The flexible curriculum, offered online, includes a wide range of learning technologies, such as purpose-built video, web conferencing, and state-of-the-art simulation software. The material covers a balance of technical, managerial, and sustainability content. The program also includes short summer field school sessions, where students gain practical application skills.

TUESDAY, FEBRUARY 21

MORNING

9:00 am **Room 107**

Bulk Material Handling: Advances in Conveyor System Component Design

Chair: *D. Bailey, CONetic Resources*

9:00 am

Introduction

9:05 am

Design and Analysis of Conveyor Pulleys using a Precise Finite-Element Model based on the Hamiltonian Form of Elasticity

A. Hustrulid; Hustrulid Technologies, Bonita Springs, FL

Conveyor pulleys are used in mining and industrial applications to change the direction of the conveyor belt and apply or remove power from the conveyor. This paper reviews the traditional design approaches for pulleys such as Sitzwohl, Lange and Schmoltzi and contrasts them with a modern precise finite element model based on the Hamilitonian form of elasticity. The applied loads from the belt, the locking assembly and the overhung load on the shaft are reviewed. Using these finite element results common industry design criteria are reviewed including shell stresses, shaft stress and deflection, end disk stresses and bending moments in the locking assembly. Conclusions are drawn regarding current pulley design methods for CEMA class pulleys, for wide, high tension but low diameters pulleys and for very high-tension pulleys being considered for ST 10,000 conveyor belt systems.

9:25 am
A Finite Element Analysis on the Troughed Belt Turnover
Y. Zhang; Conveyor Dynamics Inc., Bellingham, WA

Belt turnover is an effective way to reduce material carry-back on the return side. It reduces environmental contamination and maintenance work, and improves the idler roll life on the return side. Flat turnover has been the dominant belt turnover method. For extra wide and high duty belt, the concern is the flat turnover requires long turnover length, large space, and causes extra sag and stress in the belt. Troughed belt turnover thus is introduced to address these concerns, where the belt is folded into a troughed or semi-circular shape by guide rollers during the turnover. However, there isn't a clear and effective method to analyze the troughed turnover, due its increased complexity. There is a wide range of mechanical designs to induce the troughed belt turnover, without the clear understanding of their effectiveness. This study uses the finite element method to analyze a troughed belt turnover. The purpose is to establish an analysis tool and initial study on the intrinsic nature of the troughed turnover.

TUESDAY, FEBRUARY 21
MORNING

9:00 am **Room 706**
Coal & Energy: Best of Mine Health & Safety

Chairs: *N. LaBranche, Sintars, Brisbane, QLD, Australia*
C.Chen, Virginia Tech, Blacksburg, VA
S. Schafrik, Virginia Tech, Blacksburg, VA

9:00 am
Introduction

9:05 am
Portable Chilled Air for Underground and Surface Mining
M. Gleadhill; Anglo American, Lammermoor, QLD, Australia

Heat management in Underground Mining remains one of mining's foremost risks to both the health and safety of mine workers and the operational stability of the mine. Harnessing a phenomenon of thermodynamics, we are using mine compliant, compressed air driven, low noise level, portable "air conditioners," capable of delivering super cooled additional air to a workplace. "The Cool Tube" devices were developed for the intended use of – Cooled air on longwall faces, development faces, conveyors – Seal build sites, face drilling activities and secondary support – Confined space locations, hoppers, dragline tubs and workshops – Fixed equipment / infrastructure cooling of transformers and drives - Cooling and dehumidifying of water body areas / sumps or any work area affected by hot and or humid conditions – Frictional ignition ventilation without recirculation concerns – Positive pressure air conditioned refuge chambers, change over bases and bratticed crib area cut throughs. “The Cool Tube”, devices weigh from 6 - 8 KG and deliver on average 4° Celsius chilled air at a rate of 35 - 60L/Sec when supplied with 5 - 8 Bar of compressed air. Noise pressure levels range from 76 - 89 dBA at 1m.

9:25 am

Overview of Queensland Mining Inspectorate

R. Albury; AUS IMM, Brisbane, QLD, Australia

The paper will describe the location, structure and role of the Queensland mines inspectorate in the coal mining industry. The introduction will include a brief summary of the history of the Qld legislation and some context around the major events that have shaped the enabling framework. Following the introduction will be a description of incident details, emerging issues for the inspectorate and a description of the priority issues the inspectorate is dealing with at the present time. This will also include detail regarding the journey the Queensland industry has embarked upon in the re-emergence and subsequent changes to legislation around dust exposure and health monitoring of workers.

9:45 am

Simtars Update: Queensland Health & Safety

N. LaBranche; Simtars, Brisbane, QLD, Australia

Simtars is the Safety in Mines Testing and Research Station as part of the Queensland Government in Australia. This talk will provide an overview of Simtars’ role in providing health & safety research for the mining industry and the status of current projects and research. Each year Simtars selects one underground coal mine and implements a full scale mine disaster scenario to test the mines systems for self-escape and emergency response as well as mines rescue.

10:05 am

Managing Occupational Health in the Minng Industry

D. Cliff; Minerals Industry Safety and Health Centre, University of Queensland, University of Queensland, QLD, Australia

Wth the recent resurgence of “black lung” detection in the Australian Coal Mining Industrythe spotlight has fallen onto the health aspect of health and safety. Too often health is seen as being hard to manage because it may relate to chronic and/or extended exposure to harm. However proper application of risk management techniques including focussing on critical controls and the continued effectiveness of these controls works as well on occupational health issues as it does on safety issues. This paper will demonstrate the application of risk management to a range of health issues using the RISKGATE online bowtie methodology, including respirable dust, fatigue and psychogical impairment. The resurgence of ‘black lung” will be used as a case study to underline the need to identify critical controls and institute processes to measuer and maintain their effectiveness and not allow them to be eroded.

10:25 am
Grasstree Mine - Airodusting (the Most Efficient Stonedust Application)
D. Proffitt; Anglo American, Brisbane, QLD, Australia

Grasstree mine achieved a new benchmark in productivity in 2015 and finally did what no other Australian mine has done before, cracking the 10 million tonne mark. With such high production levels and generation of coal dust into roadways, it was necessary to rethink the way in which we apply incombustible materials to our roadways. Therefore the testing and subsequent approving of a different and more efficient method for applying stonedust (calcium carbonate) to our roadways was utilised. Underground coal mines in Queensland were required pre-2000 to have barriers installed (water barriers, stonedust barriers) at specified locations. New legislation introduced following the Moura mine disasters required that each specific roadway in the mine was fully treated to certain incombustible levels and sampled at prescribed intervals. One of the major benefits that airo-dust has over conventional dusting is that it can be done anywhere in the mine and does not generate any dust as it applies in a wet state. This also helps it stick to the walls and roof of the mine significantly better than conventional stonedust. The easiest way to describe how it applies is like shaving cream.

TUESDAY, FEBRUARY 21
MORNING

9:00 am **Room 711**
Coal & Energy: Impact of MSHA's Respirable Dust Rule

Chairs: *P. Chugh, NIOSH, Pittsburgh, PA*
J. Colinet, NIOSH, Pittsburgh, PA

9:00 am
Introduction

9:05 am
Impact of MSHA's Dust Rule
G. Meikle; Coal Mine Safety and Health Division of Health, USDOL - MSHA, Arlington, VA

On Thursday, May 1, 2014 the Mine Safety and Health Administration (MSHA) published in the Federal Register a Final Rule "Lowering Miners' Exposure to Respirable Coal Mine Dust, Including Continuous Personal Dust Monitors. The purpose of this final rule was and is to reduce occupational lung diseases in coal miners. Chronic exposure to respirable coal mine dust causes lung diseases including coal workers' pneumoconiosis (CWP), emphysema, silicosis, and chronic bronchitis, known collectively as "black lung." Based on data from the National Institute for Occupational Safety and Health (NIOSH), new cases continue to occur among coal miners. This final rule will reduce coal miners' occupational exposure to respirable coal mine dust. As a result, it will lower their risk of developing black lung disease and suffering material impairment of health or functional capacity. This presentation will review the data and experiernce from respirable dust sampling under the new rule.

9:25 am

MSHA's New Dust Regulations - the Industry's Perspective

B. Watzman; National Mining Association, Washington, DC

The new MSHA respirable coal mine dust rule has brought widespread changes to the sampling program conducted by mine operators. In order to address these new requirements multiple changes have been implemented that have impacted personnel allocations, operations, and budgets at coal mines. This has occurred against a backdrop of continued questioning of the science underlying this rule and its reach acros the entire coal industry. An overview of the impact of these changes and feedback from the coal mining industry will be provided.

9:45 am

Impact of MSHA's Dust Control Regulation

J. Roberts; Health and Safety, UMWA, Beckley, WV

Part 1: How We Got Here Before we can begin delve into the impact of MSHA's new dust rule. We have to know a little bit of history and how we got here. Part 2: Development of the rule I'll go over the long and sometimes contentious process of developing the new dust rule. Part 3: Implementation of the Rule We'll take a look at the different stages of implementation and how workers and employers adapted. Part 4: The Results are in: We look over the early results of the new rule since being implemented. Part 5: Where do we go from here? I'll go over some ideas of where we may/can go from here. As well as ways we can improve on the new rule.

10:05 am

Methods for Controlling Respirable Dust in an Underground Mining Environment

S. McQuerrey; Research & Development, JH Fletcher & Co., Huntington, WV

According to the CDC, the prevalence of CWP (Coal Workers' Pneumoconiosis) has increased after a 30 year downward trend. This has led to new regulation reducing the amount of respirable dust exposure from 2.0 to 1.5 mg/m^3. Roof bolter operators are commonly exposed to respirable dust that can lead to CWP. In association with the NIOSH, J.H. Fletcher & Co. has worked to reduce roof bolter exposure with the development of the Fletcher® Dry Scrubber and canopy air curtains. In addition to these components, improved drilling methods continue to be a way to reduce the generation of respirable dust. It is important to understand the source of the dust in order to mitigate the exposure. When the roof bolter operator is downstream of a respirable dust source in the mine ventilation, then a means of reducing exposure external to the roof bolter has shown to be a very effective method for exposure mitigation. The Fletcher® Dry Scrubber has been effective in reducing respirable dust by over 93% in lab testing. Field testing yielded an over 49% reduction when handling only part (approximately ½) of the ventilation airflow to the operators.

10:25 am **17-108**

Respirable Dust Measured Downwind During Rock Dust Application

M. Harris, J. Organiscak and S. Klima; NIOSH, Pittsburgh, PA

The Office of Mine Safety and Health Research (OMSHR) conducted underground evaluations to quantify differences in respirable rock dust generation when using an untreated rock dust and a rock dust treated with an anti-caking additive. Using CPDMs, these evaluations measured respirable rock dust levels arising from a flinger-type application of rock dust on rib and roof surfaces and during tramming of a battery scoop through accumulations of rock dust on the mine floor. Rock dust with a majority of the respirable component removed was also applied in the Bruceton Experimental Mine using a bantam duster. The respirable dust measurements obtained downwind from both of these tests are presented and discussed. This testing did not measure miners' exposure to respirable coal mine dust under acceptable mining practices but indicates the need for administrative controls to be exercised when rock dusting.

TUESDAY, FEBRUARY 21

MORNING

9:00 am **Room 704**

Coal & Energy: Mine Automation

Chairs: *T. Novak, University of Kentucky, Lexington, KY*
H. Akbari, NC State University

9:00 am

Introduction

9:05 am

The Value of Integrating Power and Process for the Mining Industry

D. Mazur, B. Venne and R. Entzminger; Rockwell Automation, Milwaukee, WI

Coordination of large distributed measurement and control systems, such as SCADA and other process control system implementations, require robust networks that connect thousands of remote devices from multiple locations. The mining industry has increasing demands of their infrastructure to handle more network services and deliver a full spectrum of control and monitoring within their global operations. Conventional methods for mining applications provide two separate domains, infrastructure and process automation that typically do not communicate. With the advancement of the industrial communications and rising energy costs, these domains can provide value to mining applications when logically integrated. Unifying the power and process systems within an operation provides value by creating a single visualization and reporting environment. This paper will outline a method of providing a convergent use of the IEC 61850 standard, within process control networks, to provide enhanced process control, monitoring and energy management. The paper will discuss benefits of a unified power and process architecture with enhancements provided by visualization, archiving, and reporting.

9:25 am 17-039

Development of an Automation Laboratory and Courses for Mining Engineering Education

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

The applications for automation continue to expand in the mining industry. These applications can range from the startup, control, and shutdown of processing plants to the autonomous operation of surface haulage trucks. However, the term "automation" should not necessarily be interpreted as the total elimination of human interventions since there are many portions of mining processes that can be automated. The future survivability of many mining operations will be influenced by a company's willingness and ability to understand, accept, and use this technology. The mining workforce, including management and engineering, should be educated on the technological capabilities and limitations to effectively implement automation into mines for improving safety and productivity. The Department of Mining Engineering at the University of Kentucky has recognized this educational gap and developed an automation laboratory, along with project oriented courses at the undergraduate and graduate levels. The laboratory and the course objectives will be described in this paper, as well as the obtained skills and abilities that students achieve at the completion of the course(s).

9:45 am

System for Managing Advanced Response Technology (SMART) in Mines

M. Momayez; Mining and Geological Engineering, University of Arizona, Tucson, AZ

We propose a new approach for mine-wide distributed sensing, monitoring and communication based on a scalable platform of nano sensors, nodes, and gateways. The system is deployed at the University of Arizona's San Xavier Mine for safety (worker health and vital statistics, emergency response, engineered environments such as ambient air quality, ground stability), tracking (accurate underground geolocation of assets such as workers and equipment), and communication (audio, video, phone conversation, making calls and sending text messages from a smartphone). Sensors such as accelerometer, gyroscope, temperature, humidity, VOC detectors, and bio-physical sensors all provide the opportunity to measure real-time, continuous conditions within the mining environment. A long-life battery provides up to 2 years of power for the nodes, as well as the emergency LED directional flashlight has been configured as part of the smart mine. The strategic placement of Wireless Nano Sensor (WNS) nodes allows all areas of the mine to be monitored, and where needed, provides the ability to install a denser array in targeted areas. The network automatically adjusts when nodes are moved or changed.

10:05 am

Automation and Control System for Coal Spirals

B. Zhang[1] and M. Mohanty[2]; [1]Derrick Corporation, Buffalo, NY and [2]MMRE, SIU Carbondale, Carbondale, IL

This paper describes the development of a suitable sensor and control system to adjust the product splitter position of a full-scale spiral. A thorough investigation was made to make use of a basic property of coal slurry that can be measured on-line to correlate it to the constituent solid density and thus monitor the change in the density gradient across the spiral trough at the discharge end resulting from the usual fluctuation in feed characteristics. An

SME TECHNICAL PROGRAM: TUESDAY

electrical conductivity-based sensing technique was preferred over a capacitive sensor to measure the density gradient using two sensor tubes placed at the critical separation zone of the spiral trough. A PIC24 microcontroller was programmed to send a signal to a DC gear motor based on the new density gradient measured in real time to turn clockwise, counter-clockwise or stay at the same position based on the difference between the conductivity measurement of the present cycle and that of the previous cycle. The automation system was validated by examining the performance of a full-scale spiral while deliberately changing factors like feed solid content, feed washability characteristics, and feed slurry ionic concentration.

10:25 am

The Integration of Automation Platforms with OEM Controls Technologies on Blast Hole Drills

C. Stacy and M. Baker; Phoenix Drill Control, Tucson, AZ

Autonomous drilling has come a long way since the first systems were deployed over 20 years ago. Today, OEM and aftermarket solutions exist that enable users to take advantage of automated drill control features and benefits. What is often lost in the discussion is the effect of application of aftermarket automation kits on the OEM control systems and established support infrastructure both in terms of technical support and parts support. While barriers to application of aftermarket technology platforms that allow the OEM control system to remain intact, Phoenix Drill Control has developed an innovative approach that protects the OEM control system and support infrastructure while allowing a common technology platform to be deployed on a mixed manufacturer drill fleet. This paper discusses the approach from a technical perspective as well as the risks and mitigation strategies used to protect the end user and their equipment.

10:45 am **17-032**

Current Progress in the Development of the webGroundControl Application

C. Newman, Z. Agioutantis and N. Schaefer; University of Kentucky, Lexington, KY

webGroundControl provides access to NIOSH ground control design software (ARBS, ALPS, and ARMPS) utilizing a web-based multiple tier architecture. Taking advantage of current internet technologies, increased internet availability (even underground), data security for cloud computing, and cross-platform compatibility, webGroundControl provides users with faster and easier access to existing ground control designs, on-the-fly calculations for infield use, and instant online collaboration between operational personnel and planning engineers. Overall, the webGroundControl package aids in the development of safer mining environments with respect to improved roof support performance, pillar stability in longwall and room and pillar mines, formation characterization, the prediction of roof conditions, etc. Through introductions to and discussions of the current back-end database development, front-end user-application interfaces, and the deployment of beta modules, it is the purpose of this paper to raise interest in the webGroundControl such that the industry will have full understanding and experience with the application before launching the product in the summer of 2018.

TUESDAY, FEBRUARY 21

MORNING

9:00 am **Room 708**

Coal & Energy: Mine Fire Prevention II

Chairs: *L. Yuan, NIOSH, Pittsburgh, PA*
M. Trevits, Xtraction Science and Technology, Inc, Pittsburgh, PA

9:00 am

Introduction

9:05 am

Examining the Resilience of a Ventilation System in a Longwall Mine: Network Modeling and Analysis of Fire Scenarios

K. Musick, E. Watkins, S. Schafrik, M. Barros Daza and K. Luxbacher; Mining and Minerals Engineering, Virginia Tech, Blacksburg, VA

There are many conditions that can cause a fire to start in or at a mine such as spontaneous combustion, electrical malfunction, ignition of methane, etc. This project will focus on network modeling of fires in a longwall mine in the United States. Fires in underground coal mines can have adverse effects on the mine ventilation system. Using MineFire Pro+ we aim to model a ventilation system at a partner mine, and identify and model fires in several key areas identified as high risk. This will include the identification and estimation of parameters entered in MineFire such as: air temperature, air density, conductivity, diffusivity, duration of fire, heat release rate, heat transfer to determine how each situation will affect the mine ventilation system. Scenarios will be analyzed to determine how resilient the ventilation system is, and to recommend best emergency response practices.

9:25 am **17-135**

The Use of Atmospheric Monitoring Systems in U.S. Underground Coal Mines

J. Rowland[1], S. Harteis[2] and L. Yuan[1]; [1]Fires & Explosions Branch, NIOSH, Pittsburgh, PA and [2]Fires & Explosion Branch, NIOSH, Pittsburgh, PA

In 1995 and 2003 the Mine Safety Health Administration (MSHA) conducted surveys to determine the number of atmospheric monitoring systems (AMS) that were being used in underground coal mines in the United States. The survey reports showed data for the different manufacturers of AMS, the different types of equipment monitored, the different type of gas sensors and their locations. Since the last survey in 2003, MSHA has changed the regulation requirements for early fire detection along the belt haulage entries. On December 31, 2009 point type heat sensors are prohibited for use for an early fire detection system, instead carbon monoxide (CO) sensors are now required. This report will examine the number of AMS currently used in underground mines in the United States to see if there is a change in their use. The locations and parameters monitored by AMS are discussed.

9:45 am 17-079

Management of Explosion Risks in Underground Coal Mines with the use of Bag Barriers

J. Schafler[1], J. Brinkman[1], C. Johnson[1], D. Humphreys[2] and T. O'Beirne[2]; [1]Mining and Nuclear Engineering, Missouri University of Science & Technology, Rolla, MO and [2]Skillpro Services Pty Ltd, Emerald, QLD, Australia

Since the year 2000, 59 miners have lost their lives to explosions occurring in underground coal mines in the US. More accurately, those explosions were methane ignitions that propagated through the mines due to coal dust involvement; despite current explosion prevention standards. There are 4 basic strategies employed to manage the risk of coal dust explosions in many other coal mining countries around the world: removal of the coal dust, wetting of the coal dust to prevent it from becoming airborne, mixing of the coal dust with stone dust to increase the total incombustible content, and explosion activated barriers which make the entire roadway inert. However, American standards only mandate the first 3 of these 4 methods. It is possible that US coal mine safety measures could benefit from the implementation of the 4th method, the use of explosion barriers. This presentation will discuss differences/similarities in barrier regulations used in other countries, as well as some potential difficulties with adapting a stone dust bag barrier system to US underground coal mines. Also, details and feedback gathered from two operating mine site trial barrier installations will be shared.

10:05 am 17-041

Development, Testing, and Proposed Application of Multiple Passive Source Tracers in Underground Mine Ventilation Systems

E. Watkins, E. Jong, K. Musick and K. Luxbacher; Mining and Minerals Engineering, Virginia Tech, Blacksburg, VA

The application of passive tracer gas sources in underground mines is particularly useful for long-term tracer gas studies, as well as studies with sources originating in permissible areas of underground coal mines. We have previously demonstrated the use of a passive perfluoromethylcyclohexane (PMCH) sources in mines, but this new work details the development and testing of multiple fluorinated sources, as well as their application in mine ventilation systems. We detail the design of sources for three gases: PMCH, PECH and PMCP, as well as corresponding release rates over the long term at multiple temperatures. The advantages and disadvantages of these sources are presented, along with their applications in understanding complicated ventilation circuits, flow through gob, and leakage.

10:25 am

Effects of Skew Angle on Cutting Tool Temperature Increment, Wear, and Performance

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

Understanding the contact mechanism between a cutting tool and rock is critical to improve excavation performance, reduce downtime of replacing bits in mining and tunneling projects, and workplace safety by reducing frictional sparking occurrence. For these reasons, a bench-scale device was fabricated and used to understand and characterize bit wear, rock excavation performance, and the temperature increment of cutting bits. With same weight machined cutting tools (S1, S2, B1, and B2) at skew angles of 0° to 18° in 6° steps, the effects of the skew angle on bit wear, rock excavation, and bit temperature increment (°C) were examined with 50-Hz infrared (IR)

cameras. First, bit tip surface area was negatively related to increment of bit temperature during friction tests. Tests conducted with B2 (largest tip surface area) revealed a significant effect of the skew angle on the bit temperature increment. In addition, bit wear of B2 and S1 was significantly reduced at 12° and 18° skew angle, respectively, when compared with zero skew angle. The results of this study will be useful for cutting bit technology, and should be informative for drum designers, civil engineers, and miners.

10:45 am

The Fire-Fighting Technology with Composite Gel – an Application for Controlling Coal Fires in No.4 seam in Bozidun, Wensu, Xinjiang, China

Y. Xiao, J. Deng, Y. Jin and Q. Li; School of Safety Science and Engineering, Xi'an University of Science and Technology, Xi'an, Shaanxi, China

Coal fire of Xinjiang China is the most serious in the world. This paper study the coal fire-fighting in No.4 seam, which is lasted over 60 years. For planning comprehensive fire prevention and extinguishment, firstly, we took the radon detecting technology to get to the fire area which was ~80000 m2, and was divided into 2 parts of east and west to control respectively. Secondly, the ground mobile system for fire prevention and extinction by grouting and injecting gel had been established, the fire-fighting material of composite gel was taken to inject in the west of the coal fire area. Furthermore, the isolation belt with gel had been established to effectively prohibit the fire extending downward. The west and east fires were all extinguished respectively by injecting composite gel. Thirdly, High-temperature regions with bigger goaf formed by combustion of coal seam were adopted the method of deep borehole blasting, and then the composite gel would be injected to the subsidence areas for achieving effective coverage. Finally, the data of CO and temperature were analyzed by arranged monitoring boreholes. It showed that the fire area has been effectively controlled.

TUESDAY, FEBRUARY 21

MORNING

9:00 am **Room 702**

Coal & Energy: Refuge Alternatives for Underground Coal Mines I

9:00 am

Introduction

9:05 am 17-113

Temperature and Humidity Tests for Mobile Refuge Alternatives

L. Yan, D. Yantek and P. Bissert; CDC/NIOSH, Pittsburgh, PA

Federal regulations require refuge alternatives (RAs) in underground coal mines to sustain life for 96 hours while maintaining an apparent temperature (AT) below 35°C. NIOSH research has shown that heat and humidity buildup is a major concern with RAs because high levels may expose occupants to physiological hazards such as heat stress. The heat transfer process within and surrounding a RA is very complex and is not easily defined analytically nor experimentally. To investigate the process, NIOSH conducted multiple 96-hour tests on a

6-person metal-type RA, a 23-person tent-type RA, and a 10-person tent-type RA in an underground mine environment. The test results show that the average measured air temperature within the RA increased by 9.0°C, 9.4°C, 11.4°C, and that the relative humidity (RH) approached 91 %, 94 %, 90 %, respectively. A comparison of the test results also show that, provided the same initial conditions, a fully occupied 10-person tent-type RA has the highest interior AT at 29.4 °C. These results may provide RA manufacturers and mine operators guidelines and considerations for determining mobile RA types and occupancy ratings for mines.

9:25 am 17-118

The Effects of Seasonal Heat and Humidity on Mine Strata Temperatures in Underground Coal Mines

P. Bissert, D. Yantek, L. Yan, J. Srednicki and J. Yonkey; NIOSH, Pittsburgh, PA

Refuge Alternatives (RAs) are required in underground coal mines to support life post-disaster. RAs are mandated by MSHA to maintain an apparent temperature (AT) below 95F while providing a safe and livable shelter for a minimum of 96 hours. Since strata composition and mine temperatures will affect the final AT within an occupied RA, NIOSH researchers have collaborated with five underground coal mines across the US to characterize the effects of geographic location and seasonal temperature fluctuations on mine air temperature, relative humidity, and mine strata temperatures. The mine which demonstrated the greatest temperature differential over the course of the year resulted in a mine air temperature that ranged from 53.4F to 84.2F and a rib surface temperature that ranged from 55.4F to 82.8F. This suggests that the location and seasonal peak temperature can significantly affect the mine strata temperature, which could lead to a fully occupied RA exceeding the 95F limit over the course of 96 hours. As such, geographic location, seasonal temperatures, and strata composition should be used to determine occupancy limits for RAs such that the mandated 95F temperature limit is met.

9:45 am

A Universal Mobile Refuge Alternative Thermal-Humidity Modeling Tool for Compliance Verification

D. Bahrami[1], C. Stewart[2] and G. Danko[1]; [1]Mining Engineering, University of Nevada, Reno, Reno, NV and [2]University of Queensland, Capalaba, QLD, Australia

The Mine Improvement and New Emergency Response Act of 2006 mandates the use of emergency rescue chambers in all US coal mines. A Universal, Thermal, Humidity, and Airflow (UTHA) model has been developed in MULTIFLUX, an advanced, high-density network model for the solution of coupled air flow, heat, humidity and contaminant transport problems. A Graphical User Interface (GUI), has been developed within the mainstream mine ventilation software, Ventsim Visual, to define the RA model and to evaluate the safe deployment of any RA in any underground mine in-situ conditions. The paper discusses the elements of the model building for a selected RA using the GUI. Application examples of tent-type, hard-shell metal, or built-in-place RA types are included with comparison of simulation results against field measurement. The acceptance of the model simulation for deciding the acceptance of an RA at a given in situ condition of an operating mine is also discussed based on the scaling demonstrations. Conclusions are drawn regarding the reduction of burden on mines and manufactures by using the UTHA model after its sufficient verification on the basis of the experiments conducted by NIOSH.

10:05 am 17-059

Estimation of Metabolic Heat for Refuge Alternative Testing

T. Bernard[1], D. Yantek[2] and E. Thimons[2]; [1]College of Public Health, University of South Florida, Tampa, FL and [2]OMSHR, NIOSH, Pittsburgh, PA

Refuge alternatives (RA) provide shelter to miners trapped underground during a disaster. RA manufacturers must demonstrate that their RAs meet the Mine Safety and Health Administration (MSHA) requirements for oxygen supply, carbon dioxide removal, and the management of heat that results from the RA occupants and mechanical/chemical systems. In this study, miner size and activity level were used to determine the metabolic heat rate, oxygen requirements, and carbon dioxide generation that is representative of miners in a refuge situation. A convenience sample of 198 male miners was used for the distribution of current US coal miners, and the composite 95th percentile height and weight were determined to be 193 cm (76 in) and 133 kg (293 lb). The resting metabolic rate (RMR) was determined to be representative of activity level in an RA. The highest likely metabolic heat generation ranged from 115 W to 135 W, depending on RA occupancy. The highest required oxygen supply and carbon dioxide removal were estimated to be 23 L_{O2}/h/person (0.81 ft^3/h/person) and 20 L_{CO2}/h/person (0.71 ft^3/h/person), which means the margin of safety is 50% or more when compared to the MSHA requirements.

10:25 am 17-087

Satisfying Apparent Temperature Requirements in Mobile Refuge Alternatives using Vapor Compression Refrigeration and Expendable Desiccant

K. Deaton; Engineering, DRS Environmental Systems, Cincinnati, OH

Research investigations sponsored by NIOSH have shown that heat buildup caused by occupants in mobile refuge alternatives (RA) will result in apparent temperatures that exceed the 95°F limit established in 30 CFR 7.504. This paper describes testing on a cooling system that uses proven vapor compression technology powered by batteries to keep the RA interior below the 95° limit for a minimum of 96 hours. Testing of a prototype cooling system was conducted in December of 2015 and January of 2016 at the NIOSH test mine. Initial testing was conducted at the prevailing cool mine ambient temperature. Subsequent testing was done with the mine ambient temperature in the immediate vicinity of the RA artificially elevated to 85°F. Results of cooling system performance at the two ambient conditions are presented. This work documents the ability of the cooling system to meet the established apparent temperature limit at the full occupancy rating of a six person RA. Larger cooling systems are currently in development and will be described. Expendable desiccant modules were also used to provide supplemental water vapor removal and their role in mitigating power consumption is adressed.

10:45 am

Implications of Coupled Heat and Contaminant Transport to RA Safety

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

Trapped miners continuously emit heat, humidity and CO_2, all to be continuously absorbed or transmitted at safe internal air conditions according to mass and energy balances. The transport of these components is strongly coupled totogether in the closed space of an RA during the containment period of 96 hours. Three critical transport interplays must be verified satisfactorily inside a closed RA: (1) body water loss by sweat and drippage vs. evaporation beneficial to cooling; (2) spatial CO_2 and O_2 concentration distributions inside the RA vs. sufficient air circulation driven by natural ventilatin; and (3) CO_2 scrubber's conversion capacity vs. air and scrubber's temperature and humidity. A CED model is presented for simulating the velocity field of natural circulation for convective cooling, evaporation, and gas transport by mixing. In addition, to advection by air movement, the model includes convection, conduction, diffusion, dispersion, evaporation, condensation and absorption. Critical thresholds are studied such as due to containment capacity overloads in the RA. Mitigation techniques for increased internal air circulation are discussed, supported by numerical simulations.

TUESDAY, FEBRUARY 21

MORNING

9:00 am Room 108

Environmental: Environmental Aspects of Tailing Management

Chairs: *R.Furey, MWH, Broomfield, CO E.Bingham, AECOM, Los Angeles, CA*

9:00 am

Introduction

9:05 am

Tailings and the Environment 101

C. Urlich; Mining, AECOM, Seattle, WA

This presentation describes the planning, design, construction, operations, maintenance and surveillance practices for tailings dams and illustrates the positive and progressive nature of our collective ability as an industry to manage tailings facilities while protecting the environment. Tailings dams are raised by optimizing downstream, centerline and upstream construction methods to fit site conditions, land constraints and mine operations and protect the environment. Tailings facilities use a variety of tailings disposal and water management methods to optimize storage space, minimize footprints, and maintain dam stability and environmental protection. Tailings dams that have failed were compromised by improper practices that could have been avoided, and so provide lessons learnt for future mine operations and environmental protection. This serious concern can be mitigated by proper and proven tailings dam and management practices with appropriate environmental controls. This presentation emphasizes the importance of integrating tailings dam development phases with each other and with the ultimate closure and post-closure phases for physical stability and environmental protection.

9:25 am

Alternative Tailings Management Technologies and Why or Why Not?

A. Watson and R. Furey; MWH, Broomfield, CO

Despite technological advances in mineral processing, mining companies still face challenges in how to best manage tailing materials. In addition, mining lower grades of ore has resulted in increased water use per unit of production; and at certain sites, water availability is the single greatest constraint on mine development. Alternative tailing disposal (ATD) has been viewed as a "silver bullet" that will address all tailing management issues, especially water concerns, the need for a smaller footprint and reduced environmental impact and risks. This presentation looks at the promise and realities of ATD methods and will provide high-level guidance on when to use individual technologies and the tradeoffs of their use compared to conventional wet disposal. The various tailing disposal types presented are: filtered, paste, thickened, and conventional disposal. Energy supply, climate, production rates, project economics, operational predictability, topography, seismicity, and water are used to frame the benefits and limiting factors behind each ATD method.

9:45 am 17-070

Holden Mine – Application of Jet Grouting to Improve Stabilization of a Tailing Embankment in a Narrow Mountain Valley

P. Crouse, J. Obermeyer and C. Weber; MWH, Denver, CO

Rio Tinto is reclaiming an abandoned copper mine near Lake Chelan in the remote reaches of north-central Washington State. The Holden Mine was one of the largest operating underground mines in the U.S. consisting of nearly 100 km of underground tunnels and 7.6 million tonnes of mill tailings. Although Rio Tinto never owned or operated the mine, they are managing and funding a several hundred million dollar clean-up to prevent future water and soil contamination. A primary component of the reclamation involved addressing the stability of a tailing embankment under seismic conditions and the potential release of mine tailings into two adjacent creeks. Due to space constraints, a creative approach using Jet Grout columns was applied to provide seismic stability and strengthen the foundation, without the need of a large rock toe buttress. This unique application required a combination of engineering analysis, investigation, field trials, and a robust quality control program during construction. The columns were anchored into non-liquefiable materials above and below the potentially liquefiable overbank and saturated tailings layer at a minimum strength of 3.45 MPA.

10:05 am

Forty Years of Mine Closure: Where Have We Been and are There Lessons for the Future?

L. Danielson[2] and R. Furey[1]; [1]MWH, Broomfield, CO and [2]Western State Colorado University, Gunnison, CO

The practice of tailing dam and mine closure has come a long way over the past 40 years. In the past mines were developed with little thought on how to close the mine, today in the industrialized countries it is now impossible to open a mine without a closure plan in place. Yet laws in many countries have failed to provide a mechanism through which a mining company can define its closure obligation and relinquish a closed mine and this inability to relinquish a mine often challenges a mining company's financial position. This presentation will take a look back at the environmental and legal aspects of mine closure and will make suggestions for the future.

10:25 am

Tailings Risk Management

D. van Zyl; UBC, Vancouver, BC, Canada

The Mount Polley and Samarco tailings failures have eroded the confidence in the mining industry to protect the safety of people and the environment. Do these failures reflect a tailings management philosophy that is not focused on zero failures or are engineers and mining companies too optimistic about their abilities to design robust tailings facilities for complex site conditions and operate these facilities despite challenges? There are clear risks associated with tailings management and it is good practice to reduce these risks as much as possible. However, zero risk does not exist and ongoing risk management is essential for all tailings management facilities. Tailings risk management is an integrated approach to the technical, operational, management, corporate governance and regulatory aspects of tailings management facilities. This presentation will highlight current approaches and will reflect on what will be required to move towards zero failures.

10:45 am

Panel Discussion: Environmental Aspects of Tailing Management

E. Bingham; Mining, AECOM, Denver, CO

The final time slot for the session will be a panel discussion focusing on the environmental aspects of tailing management. Panelists -- Dirk Van Zyl, Luke Danielson, Andrew Watson and Cecil Urlich -- will delve deeper into the issues the industry faces with respect to tailings and the environment and will debate the merits of the different approaches. The discussion will include time for audience questions and participation. Does protecting the environment mean that all new mines must filter their tailings? What about wet vs. dry closure of tailing storage facilities? How can the industry best manage these risks? Panel moderator: Eve Bingham.

TUESDAY, FEBRUARY 21

MORNING

9:00 am **Room 104**

Environmental: Responsible Mining

Chairs: *G.Sutton, The Doe Run Company, Boss, MO S. Anderson, Viburnum, MO*

9:00 am

Introduction

9:05 am

Novel Use and Treatment of Waste Streams in Mining – Two Case Studies

M. McCaslin; WesTech Engineering, Murray, UT

Out-of-the-box thinking can lead to resourceful uses for, and treatment of, wastewater. While we engineers are not noted for our creativity, two case studies reveal that inspiration is possible: 1. Secondary water from a sewage treatment plant is further polished for use as process water in gold recovery from tailings. The tertiary treatment removes solids and organics to maximize performance in the carbon-in-leach circuit. It is not only less expensive than the potable water used previously, but contains fewer impurities. 2. Regulators and industry cooperate to treat acid mine drainage (AMD) for use as process water in a nearby power plant and to make a coal seam accessible. The overall plan was achieved, if somewhat indirectly.

9:25 am

Site-Specific Prediction of Ground Vibrations Induced by Bench Blasting Using Machine Learning Techniques

A. Kumar; Mining Engineerin, Student, Dhanbad, Jharkhand, India

Blasting is a widely used method for rock fragmentation in mining. Environmental effects such as air shocks, noxious fumes, dust, fly-rocks and ground vibration are undesired effects of blasting. Among these, ground vibrations can have a damaging effect and may influence large area. Therefore, various researchers have developed mathematical models to predict ground vibrations induced by blasting. The selections of the most suitable model require engineering judgment and evaluation of models. However, site-specific blast vibration prediction can be more useful than using a universal prediction equation. In this paper, we have applied multiple machine learning techniques like gradient boosting, neural networks and PCA to predict the peak particle velocity of the ground vibrations induced by blasting using the data from an iron ore mine in North-Eastern India. The sensitivity analysis methods like garson's, olden's and PCA have been applied to get the relative importance of the variables in prediction of the output. This paper introduces and presents a model to estimate ground vibration to provide blasting engineers a tool to optimize blast design for safe blasting.

9:45 am

Corporate Social Responsibility as an Engineering Competency for the Mining Industry

N. Smith and J. Smith; Colorado School of Mines, Golden, CO

Divisions between the "technical" and "social" dimensions of mining and engineering can cast Corporate Social Responsibility (CSR) as the domain of social scientists and community relations experts. Drawing on ethnographic research with practicing engineers in the mining industry, we illustrate how CSR is inherent to their work as engineers. We examine the ways in which social concerns shape their work throughout the life cycle of a mine, and how their work blurs the lines between the social and technical aspects of natural resource development. This work suggests that CSR is not peripheral to engineering, but is a key competency required for careers in the global mining industry.

10:05 am

Engineered Biopolymer for Dust Control in the Mining Industry: Mine Haul Road Case History

L. Kuri[1], C. Landis[1], R. Falco[2] and A. Madduri[1]; [1]HPPE LLC, Columbus, GA and [2]Seatex Ltd, Rosenberg, TX

A new functionalized biopolymer is introduced as an alternative to common chloride and sulfate-based chemistries for dust suppression. Dust management on mine haul roads is one of the most challenging opportunities for the industry to improve everything from compliance to driver safety to its water footprint. In this study, dust (<74um) was measured from haul roads in semi-arid Wyoming. Stationary collectors were positioned in half mile segments of no-treatment, water-only treatment and water treatments incorporating low concentrations of engineered biopolymer. The results show not only visible reductions in dust generation, but also quantified dust reductions of at least 50%. With respect to the water footprint, daily watering was reduced by 50% for the treated road. Finally, watering was reduced to a four day program at a reduced rate after the initial seeding of the roads. Our evidence shows that the water-based biopolymer continues to immobilize potential air-borne material with additional opportunity for dust management at mineral stockpiles, conveyance and trans-loading sites.

10:25 am

Mining-Related Selenium Contamination in Alaska: State of Knowledge

A. Khamkhash[1], T. Ghosh[1], S. Aggarwal[2], G. Akdogan[1] and R. GANGULI[1]; [1]Mining Engineering, University of Alaska Fairbanks, Fairbanks, AK and [2]Civil and Environmental Engineering, University of Alaska Fairbanks, Fairbanks, AK

Selenium is one of the main contaminant elements in Alaskan mining waste streams. The most common forms of selenium released during mining processes are selenite and selenates. There are several treatment technologies such as: precipitation, adsorption, ion exchange, membrane processes and biological removal. The paper would review Selenium concentration levels in Alaskan mine and plant discharge in the past 15 years. The mitigation strategies and sources of selenium are briefly explained in this paper.

10:45 am 17-058

Environmental Issues of Artisanal and Small-Scale Mining in the Tarkwa Mining Area of Ghana

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

We made site visits to determine potential environmental issues caused by artisanal and small-scale mining (ASM) in the Tarkwa Mining Area (TMA) of Ghana. Activities of the diggers were observed to degrade vegetation, land and water. Improper handling of mercury was also identified as a major threat to people and ecosystem. Large abandoned pits and trenches posed fall traps to farmers, hunters and wildlife. We argue that lack of adequate monitoring and regulatory enforcement by Ghanaian authorities, together with inappropriate mining processes, probably due to lack of technical expertise are contributing factors to the environmental issues of artisanal and small-scale mining in the TMA.

11:05 am

Energy Management - a Smart Approach to Reducing Spend

M. Atkins; Institute of Management Consulting, Houston, TX

Most mining companies do not measure or manage their energy consumption in a systematic way. They have become locked into particular fuel sources, particular types of technology and particular mining methods. This Presentation will demonstrate that there is considerable upside when organizations begin to manage energy as a portfolio, explore flexibility across different fuel sources, embrace new proven technologies that can dramatically reduce costs and improve efficiency and drive energy metrics at a mine level. To realize gains in Energy management a systematic approach is required, which requires the organization to pull on key organization levers to drive and embed the change, Mines that overcome this can realize savings of between 15% to 50% on their energy costs. This Presentation will include the following Case Study: Facing falling commodity prices, declining grades, rising energy costs, and heightened pressure on miners to minimize the impact of operations on communities and the environment, a large global mining corporation sought to reduce its energy spend by 10% over a 5-year period - the case study will outline the steps they are taking to achieve their goal.

TUESDAY, FEBRUARY 21

MORNING

9:00 am **Four Seasons Foyer**

Environmental: Student Posters

Chairs: *B. Nielsen, Freeport-McMoRan Copper and Gold, Phoenix, AZ*
V. McLemore, NMBGMR/NM Tech, Socorro, NM

9:00 am

Introduction

9:05 am

The Characterization of Abandoned Mines in Jicarilla Mining District, NM

J. Asafo-Akowuah[1] and V. McLemore[2]; [1]Mineral Engineering, New Mexico Institute of Mining and Technology, Socorro, NM and [2]New Mexico Bureau of Geology and Mineral Resources, New Mexico Institute of Mining and Technology, Socorro, NM

Gold-silver production in the Jicarilla district, Lincoln County occurred 1892-1942 from hundreds of pits and shafts. Many of these mines were abandoned with no remediation. It is important to recognize that these early miners were not breaking any laws, because there were no laws to break. Many state and federal agencies have mitigated the physical safety hazards by closing these mine features, but very few of these reclamation efforts have examined the long-term chemical effects. Many of these mine features do not pose any physical or environmental hazard and many more, pose only a physical hazard, which is easily but costly to remediate. The objective of this research is to develop a better procedure to inventory and characterize abandoned mine features not only in the Jicarilla district, but this procedure can be applied to other districts. Hazard ranking of mine openings and features, using BLM ranking methodology will be utilized for most sites. Also we want to suggest remedial activities that would manage or mitigate dangers to the environment and public health, while taking into consideration historical, cultural and wildlife issues and mineral resource potential.

9:25 am

Evaluation of Leaching Tests on Waste Materials from the Grants Mineral District, New Mexico

Y. Li[1], I. Walder[1], B. Frey[2] and V. McLemore[3]; [1]Earth and Environmental Science, New Mexico Institute of Mining and Technology, Socorro, NM; [2]Analytical Chemistry Laboratory Manager/Geochemist, New Mexico Bureau of Geology and Mineral Resources, Socorro, NM and [3]Senior Economic Geologist, New Mexico Bureau of Geology and Mineral Resources, Socorro, NM

The Grants Mineral District, N.M., was a primary uranium district from 1950s-1980s. Uranium is mobile as uranyl and carbonate complexes, forming stable minerals in reducing conditions, especially in the Morrison Formation, a uranium-hosted sandstone in the district. Past mining and milling of uranium ore has led to contamination of water resources. Arroyos in the district have shown evidence of uranium contamination. Although, some mine sites have previously been reclaimed, contamination is still occurring and threatens local water supplies. In an attempt to determine mineral sources of the contamination and transformations associated with uranium chemistry, we are conducting preliminary leaching tests on the waste rock from selected mines to evaluate the geochemical behavior of mining material. A series of laboratory experiments are being conducted to assess the mineralogy and geochemistry of the material to estimate the leaching potential, acid generation and neutralization potential. The assumption is that if the constituent doesn't leach from the waste, then it is not a threat to the groundwater. Weekly changes will be monitored to determine leaching plateaus.

9:45 am

The Characterization of the Rosedale Mine District, Socorro County, New Mexico

A. Winton, V. McLemore and W. Zutah; Mineral Engineering, New Mexico Institute of Mining and Technology, Socorro, NM

Mining has played a remarkable role in the economic development of the United States. Despite the closure of many mine features as a way to mitigate physical safety hazards, state and federal agencies are concerned that some of these features could still pose an environmental affect after closure and some of these effects could increase due to natural hazards that occur especially in desert environments, such as wildfires and periods of regional monsoonal flow. The objective of this research is to develop cost-efficient methods of inventorying and characterizing these abandoned mine lands, using the Rosedale gold-silver mine in the Rosedale mining district, Socorro County, New Mexico as an example. By utilizing the BLM ranking methodology, along with standard kinetic column testing of waste rock material, potential physical and chemical hazards posed by these abandoned mine sites will be evaluated. Concentrations of metals will be measured in stream sediments and stream-water, collected downstream from the mine site to evaluate environmental effects following the recent burning of 42,102 acres of the North Fire in the Cibola National Forest, San Mateo Mountains.

10:05 am

Reactive Transport of U and V from Abandoned Mine Waste Sites

S. Avasarala[1], P. Lichtner[2], A. Ali[3], R. González-Pinzón[1] and J. Cerrato[1]; [1]Civil Engineering, University of New Mexico, Albuquerque, NM; [2]Los Alamos National Laboratory, Santa Fe, NM and [3]Earth and Planetary Sciences, University of New Mexico, Albuquerque, NM

In this study, we investigate the reactive transport of uranium (U) and vanadium (V) from abandoned mine wastes collected from Blue Gap/Tachee, AZ by integrating flow through column experiments, reactive transport modelling (PFLOTRAN), and electron microscopy. Transmission electron microscopy (TEM) integrated with selected area electron diffraction (SAED) and electron dispersive spectroscopy (EDS) was used to identify amorphous and crystalline U-V phases in unreacted mine waste sediments. The sediments were sequentially reacted with 18MΩ water (pH 5.4), 10mM HCO_3^- (pH 7.9) and 10mM CH_3COOH (pH 3.4) to simulate relevant oxidizing conditions encountered at the Blue Gap/Tachee mine site and investigate the reactive transport of U and V. Reactive transport simulations of mine wastes reaction with 10mM HCO_3^- and CH_3COOH suggest dissolution of U-V bearing mineral phases as a key process controlling transport of U and V, attributing difference in their release to different U and V phases, possibly to the identified multi-crystalline U-V phases. Therefore, this study provides insights of interfacial processes affecting the transport U and V in water resources adjacent to mine wastes.

10:25 am 17-031

Copper Recovery from Waste Printed Circuit Boards

N. Santa Cano; Materials and Minerals, Universidad Nacional, Medellin, Antioquia, Colombia

Printed circuit boards are potencially reciclable materials. Developing suitable methodologies for proper disposal and better utilization, brings major environmental and economic benefits. A methodology for copper recovery using heat treatment before conventional leaching is carried out. A comparison between conventional methodology and the one that includes incineration treatment is presented. It concludes about results and differences in terms of the percentage of copper leached over time. This research aims to determine how printed circuit boards incineration intervenes in the copper recovery during the leaching process and how effective it is. Also, how incineration could be changed to mechanical and dismantling methods to avoid the generation of toxic gases.

10:45 am

Metal Leaching from the Sulitjelma (Volcanic Massive Sulfide) Mining District, Norway

F. Stopa and M. Tinsley; New Mexico Institute of Mining and Technology, Socorro, NM

The Sulitjelma mining district, in Northern Norway, has produced some 26 million tons of ore. The ore deposits (VMS) were mined for S, Cu, and Zn. Ore processing and exposed waste rock has resulted in soil contamination, ARD, and leached metals into lake Langvatn. Mine adit discharge also contributes to the contaminant load on the lake. After closure the mining district was mitigated, based on little characterization data, by leading some adit water into underground mine areas and plugging lower portals. However, this failed in reducing the mass loading to the receiving environment. To understand the contamination waste dumps were sampled, with four mine areas extensively in summer 2016. Water samples were tested for Cu, Zn, Fe and SO_4. The data shows highest concentrations near an open pit mine, Furuhagen. Ten waste rock kinetic column tests will determine mineral reactions, further leaching potential, mineralogy, acid base accounting, and sequential chemical extraction. The results will be combined with water data to estimate contaminant load to Langvatn. Without this more extensive mineralogical and geochemical characterization of the district any remediation is likely to fail.

TUESDAY, FEBRUARY 21

MORNING

9:00 am **Room 102**

Environmental: Water Treatment and Water Management at Closed Mines

Chairs: *A. Martin, Foth Infrastructure & Environment, LLC, De Pere, WI*
D. Yantorno, ASARCO LLC, Tucson, AZ

9:00 am

Introduction

9:05 am

Selection and Implementation of a Post-Closure Mine Dewatering System at the Chevron Mining Inc., Questa Mine, New Mexico

T. Cox and J. Gilbert; Arcadis, Highlands Ranch, CO

The Questa Mine is a former underground and open pit molybdenum mine in Taos County, New Mexico. The underground mine was dewatered by pumping water from the lowermost haulage drift through a conveyor decline to the surface. The mine was closed in June 2014 and closure efforts included evaluation of a new surface-base dewatering system, shutdown of the existing underground dewatering system, and allowing a portion of the mine to fill. A performance objective of a new dewatering system is to maintain a mine pool elevation below the bordering Red River. Various dewatering alternatives were vetted against construction, safety, feasibility, and cost criteria, and a wellfield dewatering system was selected. Three dewatering wells were drilled using conventional and real-time directional drilling techniques, with the wells targeting the lowermost haulage drift in the underground mine. Groundwater inflow to the underground mine and the volume of workings were used to estimate the mine filling rate. A monitoring plan was prepared to monitor groundwater levels and quality in the surrounding bedrock aquifer to document that the performance objective is achieved.

9:25 am

Deciphering and Improving Sludge Quality at the Summitville Mine Water Treatment Facility, Colorado, USA

J. Stefanoff, G. Hickman, A. Campbell and S. Champlin; CH2M, Spokane, WA

The Summitville Mine Water Treatment Facility, constructed at 11,500 feet near the top of the Alamosa River watershed by the U.S. EPA and State of Colorado, treats mining-influenced water to improve downstream water quality and habitat. It has a design flowrate of 1,400 gpm and uses lime neutralization in the standard high density sludge (HDS) configuration. Due to challenging influent with high concentrations of ferric iron, aluminum, and other metals, it has experienced significant operational challenges due to viscous, sticky sludge, which is relatively slow to dewater and does not achieve desired density. CH2M was contracted to identify options, with the primary goal of producing sludge of high weight percent solids with good handling characteristics and dewaterability. CH2M conducted onsite pilot testing which optimized removal of ferric iron and aluminum, and demonstrated significantly improved sludge properties. Density was also significantly improved with the surprising exception of water from early-season snowmelt which produced a difficult to explain HDS inhibition effect. Options were developed that cost-effectively reused existing tanks and equipment.

9:45 am

The Next Big Mining Investments

D. Eyde; St Cloud Mining, Tucson, AZ

Capital requirements for mining operations will include an increasingly upward trend in investments in water infrastructure and treatment, relative to conveyors, crushers, trucks and shovels. One of the largest ongoing expenses during the life cycle of a mining operation is the treatment of effluents that leave the property. Effluent treatment requirements of mining operations, with the affiliated bonding requirements will require new long term treatment technologies. These treatment requirements continue past the economic recovery of ore at the operation. Bonding is now often required for water treatment in perpetuity. Meeting this challenge is probably one of the more difficult challenges for the minerals industry. Natural zeolites may represent a part of the solution. Their effectiveness in different technological processes has been confirmed by numerous studies on the removal of metal cations from wastewaters. They have advantages over other materials because they are cheap, and exhibit excellent selectivity for different cations. Several case studies, and US government lab testing (USGS, EPA) are examining the viability of their use under natural field conditions.

10:05 am

Passive Treatment of Mine Effluent from the Crystal and Bullion Mines, Basin Mining Area Superfund Site, Montana – Field Pilot and Laboratory Column Treatability Studies

R. Thomas[1], G. Hickman[1], D. Smith[1] and K. Edwards[2]; [1]CH2M HILL, Bishop, GA and [2]Region 8 Montana Office, U.S. EPA (retired), Helena, MT

The Bullion and Crystal Mines are abandoned mine sites located between Helena and Butte, Montana. The adit discharge at both mine sites is acidic and contains elevated concentrations of dissolved elements/metals such as aluminum, antimony, arsenic, cadmium, copper, iron, lead, and zinc. The sites are remote, at high elevation (>7,300 feet amsl), not supplied by utilities, and are difficult to access in winter. The adit discharge flow rates are relatively low and the contaminant loading is modest. Field-scale pilot and lab column studies were performed in advance of preliminary design of passive treatment systems (PTS) to mitigate adit discharge at both sites. The main components of the PTS tested include an acidity-neutralization cell (ANC) and a biochemical reactor (BCR) to neutralize acidity and remove residual trace metals, respectively. Results indicate a full-scale ANC with 6-hour hydraulic residence time (HRT) and a BCR with approximately 4-day HRT at both sites to meet treatment goals. This presentation will provide experimental design and results of the field pilot and laboratory column studies, contaminant removal rates, and recommended full-scale design at both sites.

10:25 am

DEMET Technology ARD Treatment: Economics and Revenue Potential – a Mine Site Assessment

P. James; Blue Planet Strategies, Madison, WI

DEMET electrolytically based treatment to clean, neutralize, and selectively target and transform ARD waste into value-added potentially revenue generating products is presented. Recovery of potential valuable metal salt products is illustrated for a representative ARD site and an associated economic assessment developed for the site is discussed. Comparisons and contrasts to conventional treatment and highlighting benefits and challenges to be considered for application will be presented. Implementation options for ARD scenarios and mining operations will be explored.

TUESDAY, FEBRUARY 21

MORNING

9:00 am **Room 612**

Health & Safety: Developing Mine Worker H&S Knowledge, Skills, and Abilities

Chairs: *K. McDaniel, Colorado School of Mines*
L. Guasta, Safety Solutions International, Inc., Parker, CO

9:00 am
Introduction

9:05 am
Interactive Annual Refresher Training - Innovative MSHA Compliance Tool

W. York-Feirn; Colorado Department of Natural Resources, Colorado Division of Reclamation Mining & Safety, Denver, CO

A new, innovative and effective tool for creating and delivering MSHA compliant annual refresher training was developed and released in late 2015 by the Colorado Stone Sand & Gravel Association and the Colorado Division of Reclamation Mining & Safety. Users choose from 23 modules covering a wide range of mine safety and health topics (and up to 8 hours of training) to create a unique, fresh annual refresher training session that is supplement with your site-specific content. The program includes quizzes and exercises to test information retention and allows the user to track and document the completion of modules for each participant. Exciting features such as 'You Are The Inpsector' hazard recognition exercise and the 'Mine Game' jeopardy-type section encourage enthusiastic group participation and promote effective adult learning. This new tool is available in DVD or flash drive format. Availability on a web-based platform is planned for early 2017.

9:25 am
A Workflow for Mine Safety Training using Serious Games: Design and Evaluation

L. Brown and M. Poulton; Lowell Institute for Mineral Resources, University of Arizona, Tucson, AZ

New approaches are needed to improve worker competencies in mine safety training. Following a detailed needs assessment and field studies of current training methodologies, we will develop and validate a new approach to safety training that uses advances in "serious games" to improve training workflows. Five specific enhancements will be proposed. Through serious games, the training content, practices, and outcomes may be illustrated using non-linear stories with consequence-driven game play in a realistic, "sandbox" world. Practical gaming examples will be presented, including our experiences with "Harry's Hard Choices Interactive." We will also discuss usability studies that were conducted to evaluate the serious games approach. Our studies suggest a high level of user acceptance among mine workers.

9:45 am

Knowledge Transfer at Mines: How E-Learning Technology Can Ease the Burden

A. Dean and D. Wells; Wenco International Mining Systems, Seattle, WA

Knowledge management is a growing concern for mining and other heavy industries. Many operations in these fields subsist through ad hoc decisions and institutional knowledge held by experienced personnel. However, these fields also see significant turnover as personnel retire, advance into senior roles, or migrate to other sites and operations. An aging workforce only compounds this issue. This regular turnover contributes to the vulnerability of institutional knowledge and may reduce the efficacy of these operations as a whole. As a result, facilitating the transfer of knowledge presents a major challenge for mining operations and their human resource departments. This paper demonstrates the potential for technological solutions – in particular, e-learning software – to mitigate the impact of personnel changes in mining. It shows how e-learning creates knowledge redundancy, eases knowledge transfer, and contributes to a continuity of institutional information as junior personnel move into key roles at mines.

10:05 am

Simulation Assisted Incident Command Training for Mines

C. Harman; Mining Engineering, Colorado School of Mines, Golden, CO

Mine emergencies present unique challenges when compared to other industrial locations. Using FEMA's National Incident Management System (NIMS) most mine operators will establish an incident command structure to facilitate an organized and efficient response. The Energy, Mining and Construction Industry Safety (EMCIS) Program at the Colorado School of Mines has developed a mine rescue simulator program with grant support from MSHA. Previous training utilizing the computer simulator in conjunction with an incident command structure has shown the mine rescue teams as proficient. However, many of those in incident command were unaware of the capabilities and limitations of the responders they were supposed to be in command of. It was found that mine rescue teams and fire brigades are prepared in general to respond to a mine emergency but there was room for improvement with regards to incident command. This paper will address the need for comprehensive training of personnel who would act in an incident command role in conjunction with their on-site emergency response resources.

10:25 am

Predicting Employee Success in Training and Development Programs: a Review of the Literature

M. Lutz[1] and M. Poulton[2]; [1]Custos Fratris, L3C, Tucson, AZ and [2]University of Arizona, Tucson, AZ

Each year mine operators around the world spend millions of dollars to increase the knowledge, skills, and abilities of their workforce in an attempt to increase productivity and reduce safety incidents. Unfortunately, only some of these training interventions are considered successful – employees don't always learn what is expected and more often they don't apply what they learned back on the job. What if we could predict which employees were likely to be the most successful in training programs? What if we could use these predictions to change how we design training to make it better for employees that may struggle? This talk will provide a review of the literature on the tools and methods available to predict employee success in training and development programs and provide recommendations specific to the mining industry.

10:45 am

Required Competencies for the Mine Trainer: a New Path Forward

M. Lutz[1] and M. Poulton[2]; [1]Custos Fratris, L3C, Tucson, AZ and [2]University of Arizona, Tucson, AZ

For more than a decade, regulators and researchers have suggested that mine training needs to be more engaging and effective in order to help workers learn to be safe. Researchers have called for mine trainers to apply adult learning theory to their courses and create active exercises. But, are we doing these two things enough or should trainers be adding more and doing more? How are mine trainers supposed to know what theories to apply and how to apply them? In this program we will discuss the creation of the Mine Trainer Competency Model and how it can be used to help mine trainers (and mine operators) identify the knowledge, skills, abilities and traits that highly successful mine trainers exhibit. We will provide each participant with a copy of the model and competencies for review, comment, feedback and use.

11:05 am

Evaluation Results from a Year of Leadership Development Training for Front-Line Supervisors in Western Mines

L. Guasta; Safety Solutions International, Inc., Parker, CO

The current retirement of veteran miners and influx of inexperienced workers in the mining industry is creating a unique challenge in ensuring that supervisors are equipped with skills necessary to lead workers on the frontline. The changing labor needs in the industry is attracting younger, inexperienced employees who represent a change in culture and increased risk in the safety and health environment. These challenges present the need for refined training approaches and the capture of veteran worker experience. The University of Texas at Arlington (UTA) and Safety Solutions International, Inc. has developed a NIOSH supported, two-day leadership development course for front-line supervisors in Western mines to address the immediate needs of supervisors facing a new dimension of workers. By incorporating best practice adult learning principles and a systems approach, the course focuses on the fundamental development of leaders in the mining workforce, strengthening existing on-the-job-training (OJT) practices with train-the-trainer (T3) concepts, and enabling the occupational culture to pursue a prevention practice that will move the industry closer to accomplishing “zero”.

TUESDAY, FEBRUARY 21

MORNING

9:00 am **Room 610**

Health & Safety: Innovative H&S Technology Applications

Chair: *S.Schafrik, Virginia Tech, Blacksburg, VA*

9:00 am

Introduction

9:05 am **17-131**

DPM Removal Using Micron-Scale Drops: a Novel Diesel After-Treatment?

Z. Henderson[1], L. Rojas Mendoza[1], E. Sarver[1] and J. Saylor[2]; [1]Mining and Minerals Engineering, Virginia Tech, Blacksburg, VA and [2]Department of Mechanical Engineering, Clemson University, Clemson, SC

Occupational exposures to diesel particulate matter (DPM) present significant health risks, including increased risk of lung cancer and a range of acute (e.g., eye, nose, and throat irritation) and chronic health effects (e.g., damage to respiratory and immune systems). Personnel in underground mine environments can experience relatively high DPM exposures, since mines often use heavy diesel equipment in confined spaces. In large-opening mines where ventilation is difficult, reducing exposures can be challenging despite the variety of existing control technologies. New technologies and abatement strategies are needed. Fundamental fluid mechanics and preliminary experimental work has shown potential for removal of DPM from diesel exhaust by means of thermal coagulation between DPM particles and micron-scale water drops. Here we present promising experimental results demonstrating approximately 45% (number concentration) removal of DPM from a diesel exhaust stream under low-flow conditions using a fog of micron-scale drops. A discussion of future work is also presented including challenges and experimentation necessary for scaling up such a control technology for field application.

9:25 am

Overview of InSAR Technology for Monitoring Subsidence Over Undermined Areas

N. Schaefer[1], Z. Agioutantis[1], J. Silva-Castro[1] and J. Robertson[2]; [1]Mining Engineering, University of Kentucky, Lexington, KY and [2]Illinois Mine Subsidence Fund, Chicago, IL

Interferometric Synthetic Aperture Radar (InSAR) has experienced a surge in the past decade due to advancements in technology and the proliferation of SAR-capable satellite instrumentation. Numerous technologies have been developed that stem from InSAR, such as DInSAR and PSInSAR. These technologies are of great use to the mining industry, as they can detect ground surface deformation to within a few millimeters of accuracy. Although traditional surveying techniques are widely used to detect these movements to extreme accuracy, they prove to be costly and time consuming. InSAR offers a lower cost

technique to not only detect, but continuously monitor ground deformation in subsidence prone areas. In this presentation we will discuss the advantages and disadvantages of the different InSAR techniques for detecting and monitoring subsidence. Examples will be given from urban and rural areas.

9:45 am

An Innovative Online Platform for Professional Development for Mine Ventilation Professionals

J. Stinnette, K. Luxbacher, S. Schafrik and E. Jong; Dept. of Mining and Minerals, Virginia Tech, Blacksburg, VA

Lifelong learning is important to all professionals, allowing them to stay abreast of the latest developments in their respective fields and to refresh their knowledge amongst specialties. For mining engineers and other resource professionals, lifelong learning via professional development can be scarce or difficult to access, particularly for people at remote sites with rigorous production schedules. We propose an online learning platform specific to competency in mine ventilation. Details about platform development, learning module content, and integrated pedagogical theory related to online learning and engineering education are provided. The proposed platform is free, open source, and is intended to be maintained by a committee of experts in the field. The successful deployment of this platform can serve as model for other competencies in mining engineering (e.g., ground control, safety management, sustainable practices), and will help to further elevate the practice of mining engineering and the principles of responsible mining.

10:05 am

Use of Shrinkage Compensating/Reducing Admixtures in Portland Cement Based Materials for Safer Mining and Closure Environments

J. Preskenis; Premier Magnesia, LLC, Dover, DE

Premier Magnesia, LLC, the global innovative leader in magnesium-based technologies has introduced a novel technology to combat shrinkage and cracking in Portland cement and concrete based structures. The primary use of concrete in the mining industry is to provide a safer and healthier working environment during mining and closure and/or to reduce the environmental risk potential from contamination via AMD. Commercial advances in concrete technology can provide a very impermeable material for mining applications, but cracking can still occur as a result of shrinkage. These cracks eliminate the very low permeability benefit provided by the material by allowing a direct pathway both into and out of a structure. These cracks can allow passage of both liquids and gas easily through the structure. Shrinkage is a three dimensional phenomenon in concrete and leads to delamination of the concrete. Once the delamination from the substrate begins it is typically irreversible without major repair. This work includes successful case studies of MgO-based Shrinking Compensating / Reducing admixtures.

10:25 am

Cost Effective Wireless IoT Solutions for Monitoring Fugitive Methane Emissions

W. Powers; Pix Controller, Export, PA

Liberation of coal mine methane (CMM) from sources that include ventilation air from underground mines, abandoned or closed mines, and surface mines pose challenges and face increased scrutiny. Monitoring fugitive methane emissions from these sources is expensive, relies heavily on manpower, is prone to error, and provides limited data to the end user. With the advent of the Internet of Things (IoT) cost effective wireless continuous monitoring solutions are now a reality. These systems provide sound scientific data through long-term baseline remote monitoring and real-time analysis. Remote monitoring system transmits real-time data over various wireless telemetry options to a cloud based dashboard allowing experts to analyze problems and abnormal situations. These man portable systems include integrated batteries and solar charging providing long-term deployments in remote locations saving on labor intensive manual data sampling and costly travel. As a result better data collection and measurement will improve our understanding of methane sources and trends, and enable more effective management of opportunities to reduce methane emissions.

10:45 am

Tele-Robotic Hang-up Assessment and Removal of Rock Blockages in Mining Operations Using Virtual Reality Gaming to Improve Safety

G. Baiden; Penguin Automated Systems Inc., Naughton, ON, Canada

The removal of rock blockages in cave mining operations has long been a risky undertaking especially in high overhead conditions. Moreover, the assessment of where to put charges and placement of those charges has been difficult to do, due to the lack of visibility and safe access to the area. Thus the traditional practise of the wedging of long poles with explosives on them, keeping the operator in a potentially safe location has been one of the tried and true methods of attempting to remove the blockages. Unfortunately, this is less than a perfect system usually taking several attempts to achieve the blockage removal. Each successive attempt can result in an even more dangerous condition for the worker and/or damage to the mine. Due to successively larger amounts of explosives used until the hang-up finally comes down. After understanding the process thoroughly, Penguin Automated Systems has developed a robot system capable of working in a rock blockage safely. The idea draws on the latest in telerobotics technology combined with 3D scanning and underground geospatial positioning. This paper will review the development of the system and present the results.

TUESDAY, FEBRUARY 21

MORNING

9:00 am **Room 506**

Health & Safety: Monitoring, Interpreting, and Reacting to H&S Hazards

Chairs: *J.Brüne, Colorado School of Mines, Golden, CO E.Haas, National Institute for Occupational Safety and Health, Pittsburgh, PA*

9:00 am

Introduction

9:05 am

Field Association of FLIR Airtec Real-time DPM Monitor to the NIOSH 5040 Sampling Method

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

Diesel Particulate Matter (DPM) exposure to underground miners is a worldwide issue due to the reported adverse health effects. In underground mines, the monitoring, control and treatment of diesel engine exhaust has become an integral part of mine safety and health programs. The NIOSH 5040 method is a standard technique used for DPM regulatory compliance in U.S. metal and nonmetal mines. The NIOSH 5040 method measures DPM on a shift-average basis. However, a number of portable real-time DPM monitors are now available to the mining industry. This study focuses on a comparison of extensive DPM measurements in five underground U.S. mines using a commercially available real-time DPM monitor (FLIR Airtec) and the NIOSH 5040 method. The samples were collected in metal mines which use high percent biodiesel as a primary engine fuel. The results from the two methods showed a slight bias in Airtec measurements at low DPM concentrations. A correlation equation with high correlation coefficient ($R^2 = 0.92$) was obtained. The correlation model was validated by an independent set of samples and the results were found to be satisfactory.

9:25 am

Improving Tailings Storage Facility Safety in the U.S.

O. Chernoloz[1] and M. Poulton[2]; [1]Mining and Geological Engineering, University of Arizona, Tucson, AZ and [2]Lowell Institute for Mineral Resources, University of Arizona, Tucson, AZ

Tailings storage facilities (TSFs) and water retaining dams are the largest manmade structures on Earth. Statistics show that TSFs are more likely to fail than other dams. As the scale of mining increases, TSFs increase in height and volume, therefore increasing the consequence of failure. To help mitigate risk, mining companies impanel expert groups to review operations of TSFs. In the US the MSHA has inspection authority for TSFs. We have examined the regulatory practices, the industry practices and public data on TSFs in Arizona. We address inadequacies of the official government records on TSFs in the two largest publicly accessible US databases, the

National Inventory of Dams, and the National Performance of Dams Program. Both databases contain many errors, including descriptions and geographic coordinates of TSFs that are inaccurate by many kilometers. We address these shortcomings with a pilot project for Arizona that demonstrates recording accurate information in a database is neither expensive nor onerous, communicating best practices for operation can help alleviate community concerns, and continuous monitoring technology can resolve shortcomings with visual inspections.

9:45 am

Exploring the Use of Situation Awareness in H&S Leaders Behaviors and Practices

D. Willmer; NIOSH, Pittsburgh, PA

Gaining an understanding of how health and safety management systems (HSMS) reduce worksite injuries, illness and fatalities can occur in studying the behaviors and practices of health and safety (H&S) leaders. These leaders bear the responsibility for identifying, understanding and managing the risks of a mining operation. More importantly they have to transfer this knowledge of perception, recognition and response to risks in the mining environment to their workers. The leaders' efforts to build and maintain a mining operation's workforce that consistently executes safe work practices can be captured through more than just lagging indicators of health and safety performance. This exploratory study interviewed six site level H&S leaders at U.S. surface and underground stone/sand/gravel and metal-non-metal mine sites with employee populations of 40 to 175. In exploring leaders' perspective on how they systematically manage health and safety, examples such as approaches to task training, handling near-miss incidents, and building a leadership pipeline offer insights into leaders' use of situation awareness to manage site level risks and how they work to communicate it to others.

10:05 am **17-050**

Effects of Corrosion on Ground Support and Corrosion Monitoring Methods

A. Chambers[1], D. Benton[1], M. Stepan[1], S. Finley[1] and D. Orr[2]; [1]NIOSH, Spokane, WA and [2]Hecla Mining Co, Juneau, AK

Corrosion of ground support can lead to falls of ground that pose a significant risk to miner safety. To address this problem, the National Institute for Occupational Safety and Health (NIOSH) is investigating corrosion at the Hecla Mining Company's Greens Creek Mine, Juneau, Alaska, USA. Field studies have used photogrammetry surveys to document welded-wire mesh corrosion, and laboratory studies have investigated the effects of corrosion on ground support integrity. Findings show that (1) corrosion monitoring through photogrammetric methods may be effective for qualitative measurements of welded-wire mesh corrosion, and (2) there is a relationship between loss of load-bearing capacity and the diameter loss due to corrosion in welded-wire mesh. Photogrammetry results thus far have measured an apparent bulking of the corroded welded-wire mesh, and preliminary laboratory tests have investigated the relationship between the larger bulked and effective wire diameter. If this relationship is verified, these results may indicate that photogrammetry, combined with the models produced in laboratory tests, could offer a means of monitoring corrosion levels, as well as rock rib deformation.

10:25 am 17-027

Comparison of Underground Coal and Trona Mine Seismicity

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

Recent studies of underground coal mine seismicity using a novel finite element technique that allows for whole mine analysis show strong correlations between event count, face advance and element failures. The analysis technique of dual node – dual mesh allows for whole mine analysis at the kilometer scale where surface subsidence is of interest and at the meter scale near a working face where details of stress distribution is important to safety. Variability of strata properties, jointing and topography are taken into account as mining progresses. While there are strong similarities between the coal mines studied in central Utah and underground trona mining in southern Wyoming, thereare noticeable differences. Application of the dual node – dual mesh technique indicates the difference in mine seismicity is largely attributable to differences in the strata properties and element failures and thus offers a simple engineering alternative to seismic system installation and monitoring.

10:45 am

Geohazards - Early Detection, Avoidance and Countermeasures

G. Brunet[2] and E. Michiels[1]; [1]Maccaferri Mining Solutions, Lithia, FL and [2]Maccaferri Inc, Williamsport, MD

Rockfalls are a serious and common occurrence in mining operations. Mining inherently destabilizes ground conditions while vibrations and environmental conditions exacerbate the situation. Understanding the changing strata and hydraulic movement within the mine face can provide direction on blasting. Wall height plays a significant role in how far debris will move horizontally as that distance is proportional to the height. Benches are often designed to ensure global stability is addressed, but is the bench wide enough to catch debris should it fall? Freeze-Thaw cycles will also have a significant impact as water seeping between cracks will drive a wedge between the loose materials and push it outward. How do you secure the face in this environment? Being able to recognize surficial erosion and potential landslides or global stability issues are important in maintaining a safe working environment. Understanding early detection of these issues can help deploy countermeasures such as: precision blasting, installation of screens and meshes or when a barrier may be needed to protect equipment below.

11:05 am

Working Minds: Suicide Prevention and Mental Health Promotion in Mining

T. Buchholz[1] and S. Spencer-Thomas[2]; [1]MarGeo Inc, Arvada, CO and [2]Carson J Spencer Foundation, Denver, CO

Mining continuously strives to make safety management a core value and practice – aiming toward attaining zero incidents and injuries. Still, a recent report by the CDC found construction/extraction ranks #2 for occupations with highest suicide rates and #1 for highest numbers. Thus, recently an expanded emphasis on behavioral safety approaches challenges business owners to widen definitions of what it means to value health and safety. A construction/extraction industry initiative addressing mental health and suicide prevention is ushering in a new frontier for safety. Sadly, too many business owners have faced the tragedy of losing an employee to suicide. Because mental health conditions and suicidal thoughts are often invisible to the outside world, many people do not realize how common these challenges are.

This presentation lets mining leaders know they are not alone when facing these challenges and provides proven strategies in building a comprehensive and sustained approach to saving lives. Using science, stories – and even a touch of humor – the presenters engage and inspire participants and invite them to "be bold" to lead their companies in psychological health and safety.

11:25 am

Mine Emergency Risk/Readiness Self-Assessments – a Pro-Active Approach

W. York-Feirn; Colorado Department of Natural Resources, Colorado Division of Reclamation Mining & Safety, Denver, CO

An effective, rapid and easy to use pro-active tool for underground coal mine operators to self-assess their risks for a potential mine emergency, and the preparedness to respond to an emergency were developed through a partnership between the mining industry, states, MSHA tech support, and ABS Group, Inc., a risk management consultant, in 2013. Four models were developed via industry input that : (1) assess the mine-specific risks at a particular mine and evaluates (2) the mine's overall preparedness to respond to an emergency, (3) readiness of mine rescue teams to respond, and (4) readiness of responsible persons to execute the emergency plan. The self-assessments were enthusiastically received at underground coal mines and by mine management in Colorado and West Virginia and the models were refined according to the insightful feedback received from the 9 assessments completed. The results of these assessments pinpointed individual mine risk and readiness deficiencies and help mine management prioritize the gaps and devise action plans to quickly address them. The assessments allowe them to track their progress, share best practices potentially lower insurance rates.

TUESDAY, FEBRUARY 21

MORNING

9:00 am **Room 110**

Industrial Minerals & Aggregates: Critical Minerals

Sponsored by thyssenkrupp Industrial Solutions

Chairs: *S. Ravishankar, Solvay, Stamford, CT*
H. Kim, Chonbuk National University, Jeonju, Korea (the Republic of)

9:00 am

Introduction

9:05 am

Lithium and Vanadium: Critical Metals in Energy Storage

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

At the 2015 US Energy Storage Summit, financial analysts projected the energy storage space to grow exponentially in the next decade with investment totaling 150 billion dollars in the said period. Currently, lithium-ion batteries account for 70% of all batteries deployed worldwide. Global battery consumption has increased 80% in two years to 70 GWh in 2015, of which electric vehicles accounted for 35%. Vanadium flow batteries are displacing lithium-ion batteries in a number of grid energy storage applications such as load-levelling, emergency back-up, and rural electrification. Advances in technology enable vanadium flow batteries to be competitive at equal or lower cost per KWh relative to lithium-ion, when measured in terms of levelized cost of electricity. This scenario suggests that future energy storage demands will make use of both battery technologies and as a result, new sources of lithium and vanadium will be necessary. This paper summarizes the current state of exploration for lithium and vanadium as well as compares the advantages of each battery technology.

9:25 am

Global Supply Side Analysis and International Trade of Rare Earth Element – Yttrium

K. Zhang and A. Nieto; Energy and Mineral Engineering, Penn State University, University Park, PA

The supply of various rare earth elements (REEs) have been of great concern over the last decade. This research examines the global supply side of Yttrium, the most commonly used rare earth element in new lighting technology, wind turbine additive, and other renewables for a sustainable society. Yttrium currently comes largely from only a few areas in south China, increasing the resulting economic vulnerability in short term. In the medium term, however, the supply threat for Yttrium may decrease as more sources become available. In south China, which is the major source of world Yttrium supply, Yttrium is produced with other REEs. As Yttrium's content is high in the ion adsorption clays in south China, its supply is not likely to be disturbed by price changes of other co-products. In north China (Baiyun Ebo), where the content of Yttrium is lower, rare earth elements are usually produced as by-product of iron. Meanwhile, Yttrium production causes a variety of environmental/sustainability issues, making the supply stream vulnerable to more stringent environmental politics.

9:45 am

Coal and Coal Byproducts: a Resource for Critical Materials

J. Groppo[1], R. Honaker[1], R. Yoon[2], G. Luttrell[2], W. Zhang[1], C. Eble[3] and J. Hower[4]; [1]Mining Engineering, University of Kentucky, Lexington, KY; [2]Mining and Minerals Engineering, Virginia Tech, Blacksburg, VA; [3]Kentucky Geological Survey, University of Kentucky, Lexington, KY and [4]Center for Applied Energy Research, University of Kentucky, Lexington, KY

The U.S. Department of Energy has recently identified a list of critical elements that are needed to ensure the ability to provide a sustainable source of clean energy of which several are rare earth elements. The supply of these rare earth elements (REEs) is a significant national concern given that the source is mainly from international markets. Recent studies have found that the national demand for REEs could be met as a byproduct from the production of coal. In this study, coal samples from three different coal basins were characterized for REE content and the distribution quantified within the seam as well as by particle size and density. The REE content of fractions created using standard froth flotation tests were also evaluated. Finally, the overall amount of REEs in the coal and coal waste at a number of processing plants were quantified.

10:05 am 17-101

Rare Earths in Review - a Decade of Decline & Deception

J. Kennedy; ThREE Consulting, St. Louis, MO

The Rare Earth issue began its journey to prominence in 2007 as the finance industry maneuvered to re-launch Molycorp as an Initial Public Offering. The Molycorp Mountain Pass deposit was far from ideal, as it only contained the lower-value half of the 17 rare earth elements. This unfortunate reality was concealed from investors, Congress and the Pentagon by promoting an over-simplistic narrative that embellished Molycorp's historical supply, geochemical & metallurgical contributions and capabilities. The consequences of this façade have greatly contributed to the decline of U.S. and non-Chinese national economies and national security. How did this happen in full view of the SEM ?

10:25 am

Peat Based Sorption Media: a New Method for Treating Mine Drainage

P. Eger; Global Minerals Engineering, Hibbing, MN

Mine water often contains trace metals that must be removed prior to discharge. Conventional treatment technologies are labor intensive and expensive. Peat-based sorption material can be a less expensive alternative and is easily deployed in either "semi-active" or passive treatment designs. The media is a hardened granular material produced from reed sedge peat, with a hydraulic conductivity of around 1 cm/sec and metal removal capacities ranging from 1 -15% dry weight. The media has been used successfully to remove copper, aluminum, lead, zinc and cadmium. Treatment efficiencies range from 75% for fine particulate metal to over 90% for dissolved metals

10:45 am 17-003

Lithium Extraction from Hard Rock Deposits

M. Aghamirian[1], T. Grammatikopoulos[2] and C. Gibson[1]; [1]Mineral Processing, SGS Canada Inc., Lakefield, ON, Canada and [2]Mineralogy, SGS Canada Inc., Lakefield, ON, Canada

Lithium is a silver-white alkali metal that has recently become an exploration target for many junior mining companies. The current popularity of lithium can be attributed to increasing demand for lithium ion batteries. The main lithium-bearing minerals occur globally in pegmatites and granites. Spodumene ([$LiAl(Si_2O_6)$] is the most attractive economic lithium bearing mineral due to its high lithium content (theoretical Li_2O content of about 8 wt%). There are a significant number of spodumene deposits across Ontario and Quebec, which are well suited for lithium ion battery applications. Over the past several years, SGS Lakefield has been involved with a number of lithium projects across Canada with the objective to develop a process flowsheet that generates a spodumene concentrate containing at least 6.0% Li_2O (~75% spodumene), followed by a hydrometallurgical process to produce lithium compounds for use in lithium ion batteries. This paper discusses a number of hard rock lithium flowsheet development case studies, including a review of the use of dense media separation (DMS), flotation, magnetic separation, and roasting as means to process spodumene bearing ores.

TUESDAY, FEBRUARY 21

MORNING

9:00 am **Room 112**

Industrial Minerals & Aggregates: Mine Planning (Aggregates)

Chair: *K.Kosloski, Luck Stone, Richmond, VA*

9:00 am
Introduction

9:05 am
Mine Portal Protection

F. Stevens and H. Gibson; Cowin & Company, Inc., Birmingham, AL

Mine portals are critical locations for underground mines and tunnels. In additional to the safety and regulatory concerns related to portals, a failure at this location can shut down mining operations by compromising primary or secondary access, ventilation, product removal or multiple combinations of the same. Some common portal failure categories will be reviewed as well as the specific characteristics of a portal opening that contribute to increased risks of these failure types. The structural integrity of the rock at and near the portal always leads the list of considerations. However, other common points of concern that will be discussed include protection from the rock fall potential of adjacent highwalls, flooding, ice (and other seasonal changes), visibility, traffic and width/height/weight/grade restrictions, ventilation direction, groundwater, blast damage, and vegetation. Examples of portal protection challenges and remediation options will be discussed.

9:25 am
Load and Carry: a Viable Alternative

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

The Application Engineering department within Komatsu America Corp. (KAC) was asked by a customer to conduct an evaluation of a Load and Carry operation in a high production application. The mine site had little experience with a load and carry operation. Consequently, this study had to encompass the key variables that can affect the production of a wheel loader fleet. Due to the complexity of operating multiple wheel loaders in a limited area, and the uncertainty with the implementation of a new mining technique, this study also had to deviate from producing a finite result. Thus, KAC created a series of dynamic tools that allow the consideration of numerous performance variables and production targets. Known Load and Carry application data was used to define typical cycle component times, and a multiple-server machine servicing model was utilized to project wheel loader interaction, and subsequently the impact of such interaction on productivity. This presentation describes the processes used to perform this exercise.

9:45 am

Producing Fundamental Mapping Products from sUAS Data

L. Graham; Engineering, GeoCue Group, Inc., Madison, AL

The use of Structure from Motion (SfM) point clouds collected from low altitude drones has skyrocketed in the past several years. Vendors of systems and workflows offer a wide variety of standard mapping products, from ortho images to topographic contours. However, little is being said about the techniques used to achieve the accuracy levels of the various products or, indeed, of the products themselves. In this paper, we present the common products generated in the course of small unmanned aerial system (sUAS). These products are examined from an accuracy and precision perspective. We then examine how the required level of network and/or local accuracy can be achieved in sUAS operations. Finally, we present a comparison of three different levels of sUAS data collection; a high end multirotor with PPK positioning, a mid-range wing with RTK and a very low end consumer grade quadcopter with navigation grade GNSS only. Participants in this presentation will gain an understanding of sUAS mapping terminology and the approaches that must be taken to generate the products used in their day to day operations.

10:05 am

2015 Hickory Sandstone Exploration Summary Voca, Mcculloch County, Texas

M. Lee; Westward Environmental, Boerne, TX

In late 2015, the Westward Geological Services group cored over 2,700 ft. of the Cambrian-aged Hickory Sandstone Member of the Riley Formation in Voca, McCulloch County, Texas. This area of Central Texas has long been known for its silica sand deposits which are used for making glass and proppant, or frac sand. Performance of the ‘Brady Brown’ is comparable to its cousin the ‘Northern White’ in many areas. This presentation will discuss the methodologies and results from this exploration event.

TUESDAY, FEBRUARY 21

MORNING

9:00 am **Room 212**

International I

Chairs: *M. Gavrilovic, GR Engineering Services, Denver, CO*
D. Malhotra, Resource Dev. Inc., Wheat Ridge, CO

9:00 am

Introduction

9:05 am
Palmarejo Mine Transformation
J. Diaz; Colorado, SME, Chihuahua, Chihuahua, Mexico

Abstract: Palmarejo Mine transformation. Mining operations are entrusted with the task of delivering their corporate goals. This is not an easy task given the uniquely challenging operating conditions, and Palmarejo Mine (PJO) is not the exception, PJO has changed significantly since 2013, at the time, the 6000 tpd. process plant was fed by nearby open pit and underground operation. Three years later, PJO is a 4000 tpd process plant feed by two underground operations in a growing exploration district, but this is the perceived change just on the surface, the most important transformation has happened on safety, management and operational culture at all levels of organizational structure. This transformation has happened during a challenge time for the industry as declining metal prices were reigning on precious metals and Palmarejo Mine was facing a rapid decrease of mineral resources inventory. The pressure to develop and execute a strategy with no failure, in a record time was imperative. This paper describes how these changes were implemented to support a successful transformation and how Palmarejo team is getting ready to overcome new challenges in an always changing environment.

9:25 am
Recruiting Internationally - Challenges & Considerations
B. Lundblad; Mine Staffing International, Carlsbad, CA

Human resources challenges continue to cast shadows over the mining industry. The aging workforce, loss of industry knowledge and experience, a lack of young people with the right skills to fill vacant positions, will present the mining sector with critical challenges in meeting future needs. Then when you add additional hurdles of recruiting and placing general and project management personnel internationally, it's not easy finding and selecting competent people that want to work internationally, have language skills, and also have the social/technical/interpersonal skills to pull it all together in difficult far-away places. We will need to have strategic Recruiting plans in place. Post and Pray won't work. As the war for talent grows, it is ever more important to make sure you have your strategic recruiting plans in place to determine what kinds of jobs and how many, and then be absolutely determined to be smarter than ever in hiring. This paper looks at the challenges and considerations of recruiting internationally from three perspectives - the hiring company, a professional recruiter's insight, and the candidates themselves.

9:45 am 17-124
Until the End and beyond: the Sustainable Development Strategy of the German Hard Coal Mining Industry
J. Kretschmann; TH Georg Agricola University, Bochum, Germany

In 2007, a political understanding was arranged to phase out German hard coal mining in a socially acceptable manner by the end of 2018. This decision required a new strategy for the coal mining industry. German coal mining is strictly finalized and has to be prepared for the post-mining era. To make a sustainable development strategy; the long-term impacts of mining activities in Germany concerning the environmental, economic and social dimensions will be analyzed systematically and forward-looking. The regional and social responsibility of the coal industry during the closing process and for the post-mining era after 2018 will be emphasized. Environmental protection and post-mining technologies, as well as the development of mine sites to create new jobs are significant from an international point of view and are likely to attract worldwide attention. The sustainability strategy of the German hard coal mining industry can be regarded as a role model for other mining countries and regions facing similar transition challenges.

10:05 am

When Old Ideas Dissuade New Students: Teaching Mining Sciences in Sweden

T. Jones; Mining and Rock Engineering, Department of Civil, Environmental and Natural Resources Engineering, Luleå University of Technology, Råneå, Sweden

The Luleå University of Technology (LTU) is the only mining school in Sweden, and the country's premier location for education in rock mechanics. Located less than 70 miles from the arctic circle, it is near to major deposits of zinc, copper, lead, gold, silver, molybdenum, and of course, iron. The nearby Kiruna iron mine is the world's-largest underground iron mine and the most technologically-advanced underground mine in the world. These factors are placed against a highly environmentally-conscious, and equality-conscious culture where mining has acquired an undeserved reputation for unacceptability. Old environmental concerns and concerns over racial and gender equality within the industry persist. Young people raised in this culture acquire a distrust of the mining industry which creates difficulty in attracting and keeping university students in the mining sciences. This paper looks at the efforts taken at LTU to attract, retain, and educate students in mining engineering. A new CDIO initiative, industrial partnerships, redesigned courses, and re-education all play a crucial role in improving the student's opinions of mining, and in providing them with a high-quality education.

10:25 am

Seeking Better Investment Returns through Social Risk Management: from Exploration to Closure

M. Upton; SRK Consulting, Denver, CO

Investors and companies involved in exploration, acquisition, operation and closure of mining properties face social risks. These can manifest as minor disruptions to business activity or permanent suspension of a project. Social risks can be more challenging to manage than many technical risks because the likelihood and the severity of negatives outcomes is hard to predict. However, a rigorous approach with predictive capability can allow managers to mitigate these risks. For investors or project acquirers, socially-flawed projects can provide the highest return on investment as these hard-to-quantify risks may place a disproportionate discount on the property. This presentation will discuss social risks to mining properties and tools to determine their nature and extent, in the context of industry case studies. Participants will learn ways to potentially identify developing conflicts before they manifest, as well as ongoing monitoring through traditional and digital methods. Using these, managers will be better able to manage or avert social risks, and even turn them into competitive advantages in the marketplace for mineral projects.

10:45 am 17-029

Contribution of Mining Industry to Sustainable Development of Territories: the Latin American Case

O. Restrepo Baena, G. Aristizabal and A. Delgado; Materials and Minerals, Universidad Nacional de Colombia, Medellin, Antioquia, Colombia

Mining industry as a source of raw material is essential to society however, it lacks of good reputation due to the type of management historically applied to many of its social and environmental impacts. It is argued that this situation has hampered the obtaining of social license to operate of a lot of mining projects around the world. The last considerations are very common in Latin American countries. Contributing to the development of territories around mining projects constitutes a fundamental aspect of the business competitiveness through reducing cost and risks of stopping projects, innovating new ways of relationship with stakeholders, improving the level of reputation of the industry as well as its position in the market. However, this contribution requires formal strategies and models that enable companies understand the different resources in the territories where their mining activities are developed and those resource transformations, in order to establish the best way to articulate the project with the territory, pursuing an effective contribution to its development, truly sustainable over time even after the mine closure.

11:05 am

Opportunities and Realities Faced by Mining Companies Entering Colombia

C. Barrera; South America, John T. Boyd Company, BOGOTA, Colombia

Carlos Felipe Barrera. Master of Commerce & International Business (University of New South Wales, Australia) 2001. Currently Managing Director of South America for John T. Boyd Company Although Colombia's ranking as an attractive mining destination has been recently effected by commodity prices and internal struggles, the country remains an appealing target given its geological potential and strategic location. Coal, metals, emeralds and industrial minerals are the main focus of local and international investment in the mining sector. Government efforts to further advance the knowledge of the country's mineral endowment have been significant but are shadowed by weak social and environmental regulatory frameworks that discourage investors. Mining companies that are newcomers to the Latin arena face multiple difficulties including lack of international standards, complex institutional structures, high government take and increasing social and environmental requirements. Colombia is an example of challenges and opportunities.

11:25 am

Dry Stack Tailings – the Importance of the Complete System

M. Blois and M. Erickson; Business Development, TAKRAF USA, DEnver, CO

Within the last couple of years, there have been two significant failures of tailings impoundments. The first of these highly publicized failures was at the Mount Polley mine in British Columbia, in 2014. The second at the Samarco mine in Brazil in 2015, which sadly involved significant loss of life. These have focused the attention of regulators and investors on the environmental and social license to operate risks associated with tailings impoundments. Further, they have highlighted the potential financial implications, both compensatory and punitive, that result from these failures. The use of the Dry Stack Tailings approach is becoming increasingly recognized as a method of mitigating the risks, both technical and financial, associated with tailings impoundments. The Complete Dry Stack Tailings System comprises the geotechnical aspects of the stack itself, the stacking plan, the mode of transport of the tailings to the stack, the filtration stage and the thickening stage. This paper will discuss TAKRAF's decision making logic of each of these stages and it will emphasize the necessity of iterative communications between those involved with each of the stages.

TUESDAY, FEBRUARY 21

MORNING

9:00 am **Room 210**

Mineral Valuation I: Case Studies and Methodologies

Chairs: *B. Guarnera, Broadlands Mineral Advisory Services Ltd.*
M.Shumway, The Ohio State University, Worthington, OH

9:00 am
Introduction

9:05 am
The SME Valuation Standards – Present Implementation and Future Role

T. Ellis; Ellis International Services, Denver, CO

In January 2016, SME published its "SME Standards and Guidelines for Valuation of Mineral Properties, First Edition, 2016" (SME Valuation Standards). The standards closely align with the "International Mineral Valuation Template," under development by the International Mineral Valuation Committee (IMVAL) since 2012. The author, who chairs the SME Valuation Standards Committee, will address the purpose and application of the standards within the global setting of standards and financial regulations. He will then provide his expectations for continuing enhancements to the SME Valuation Standards and improved harmonization with the other major mineral valuation standards, such as the Canadian CIMVal Standards.

9:25 am
A Critique of the "Apprised Value" Method for Valuation of Grass Roots Mineral Properties

J. Botin[1] and G. Davis[2]; [1]Mining Engineering, Universidad Politecnica de Madrid, Las Rozas, Madrid, Spain and [2]Economics and Business, Colorado School of Mines, GOLDEN, CO

Most internationally recognized mineral property valuation standards consider four stages of property development: Exploration, Mineral Resource, Development and Production. Depending on the stage, three valuation approaches are recommended. These are: the Income Approach, the Market Approach and the Cost Approach. For mineral properties at the "exploration" stage, the Cost Approach is a primary methodology. Within this approach the “appraised value method” (Roscoe, 2002) is often used. The appraised value method is based on the premises that the fair market value of an exploration property is the sum of the meaningful past exploration expenditures and warranted future costs to test remaining exploration potential. The “appraised value method” carries two important limitations: i) The value of the property is only determined by past and future exploration expenditure; and ii) The value impact from a possible future discovery or lack thereof is not considered. This paper focuses on the merits and limitations of the “appraised value method” for the valuation of greenfield exploration properties and suggests a new conceptual model that takes geological context into account.

9:45 am

The Market Capitalization Approach to Valuation

G. Davis; Economics and Business, Colorado School of Mines, Golden, CO

There is considerable distrust of the market capitalization approach to valuing mineral assets. CIMVal lists the approach as a secondary valuation method, and the SME Valuation Committee’s comments to the IVSC indicate disagreement within that committee as to the approach’s validity. This paper provides the theory and practice of the capitalization approach, showing where it may be useful and were it may not be useful. It certainly should be considered a primary approach in single asset companies or in companies where a single asset dominates its portfolio. Worries that the capitalization approach does not take into account acquisition premia are easily addressed.

10:05 am

Sensitivity Analysis: Tools for Litigation in Rapidly Changing Markets

Z. Smith; Congdon & Company, Endicott, NY

Since Fall 2014, oil & gas markets have experienced unprecedented volatility with prices fluctuating, in some instances, by over 40% in six weeks. Volatility also results in fluctuating discount rates as risk increases or decreases and may drive financially distressed firms to alter expense deduction practices. This can result in dramatic differences in value over short periods of time rendering direct comparison of “expert” reports submitted for litigation difficult and confuse clients, attorneys, and judges. Sensitivity Analysis can be used to bridge the gap between reports, provide a “test of reasonableness” for opposing reports, and give the stakeholders a framework through which to reconcile differences. This is especially important in localities with relatively few competent oil & gas appraisers where values are frequently dramatically overstated, either through application of incorrect methodology or appraisal of the wrong ownership interest.

10:25 am

Thoughts on Valuing Deep Sea Manganese Nodule Deposits in the CCZ

C. Wyatt; Mining and Management, South Dakota School of Mines, Rapid City, SD

The existence of deep sea manganese nodules in the Pacific Ocean has been known for some time. Manganese nodules deposits in the Clarion Clipperton Zone (CCZ) have underwent two periods of active exploration and development. The first period lasted more than a decade and ended in the 1980’s, with millions of dollars spent but without sustained commercial production. The second period is less than a decade old and is ongoing. Countries and companies are again spending millions of dollars on exploration and development. The level of expenditure indicates there should be substantial value in the development of this resource. This paper looks at how applying standard mineral valuations techniques to a hypothetical manganese nodule deposit located in the CCZ and how the resulting values compare to the level of expenditure.

10:45 am

Gold Property Transaction Trends 2014-16 Using a Common Comparison Metric

W. Roscoe; RPA Inc., Toronto, ON, Canada

We have reviewed transactions over the past three years on more than 100 gold properties containing mineral resources and mineral reserves. The property values derived from the transactions have been normalized in terms of $/oz contained gold or gold equivalent where gold is the dominant component. Another useful metric for comparing resource properties is the Metal Transaction Ratio (MTR) which is the $/oz value divided by the gold price at the transaction date, or its mathematical equivalent, the property value divided by the in situ dollar content of the mineral resources/reserves. Trends in $/oz value and MTR are examined over the three year period for the properties, in different stages of development, in different political jurisdictions, and with different resource/reserve sizes.

11:05 am

The Impact on Mineral Property Valuations of the Proposed SEC Reporting Requirements for Mining Properties from Technical Perspective

B. Guarnera[1] and J. Fogani[2]; [1]Broadlands Mineral Advisory Services LTD, Las Vegas, NV and [2]Energy, Power, and Natural Resources, Haynesboone, Denver, CO

The SEC has proposed new requirements for Registrants with mining properties or operations. The purpose of the new requirements is to bring the SEC standards into accord with other geographies regarding the reporting for Mineral Resources ad Mineral Reserves as well as for exploration properties. These new requirements will have an impact on valuations performed on mining properties and other mineral assets. Mr. Fognani will review the legal implications of the changes on valuations and Mr. Guarnera will review the technical implications on valuations.

11:25 am

The Impact on Mineral Property Valuations of the Proposed SEC Reporting Requirements for Mining Properties from Legal Perspective

J. Fogani[2] and B. Guarnera[1]; [1]AIMA, Marietta, OH and [2]Energy, Power, and Natural Resources, Haynesboone, Denver, CO

The SEC has proposed new requirements for Registrants with mining properties or operations. The purpose of the new requirements is to bring the SEC standards into accord with other geographies regarding the reporting for Mineral Resources ad Mineral Reserves as well as for exploration properties. These new requirements will have an impact on valuations performed on mining properties and other mineral assets. Mr. Fognani will review the legal implications of the changes on valuations and Mr. Guarnera will review the technical implications on valuations.

TUESDAY, FEBRUARY 21

MORNING

9:00 am **Room 502**

Mining & Exploration: Geology: Mining Geotechnical

Chair: *C. Rehn, Barr Engineering*

9:00 am

Introduction

9:05 am **17-110**

Safety Factor Design Analysis; Intergration of Bolts, Mesh, and Shotcrete Support in Weak Rock Masses, Turquoise Ridge Mine, Nevada

L. Sandbak; Tech Services, TRJV; Barrick, Winnemucca, NV

Current ground support is based on empirical design of weak rock masses typically encountered in the ore body in an underhand cut and fill gold mine. The primary safety factor is based on bolts only, while the shotcrete and wire mesh provide a local safety factor to account for the rock between the bolts. This report quantifies the safety factor and optimum design parameters including mesh and shotcrete into the design of topcut, tertiary, and development drifts not associated with backfill or cemented rock fill design. The safety factor for ground support from bolting is described by Pakalnis (2014), and the design capacity of the shotcrete is based on the rock mass rating (RMR) and empirical methods described by Bieniawski and Larson (2013). Current ground support procedure is for shotcrete placement after bolts and mesh have been installed to prevent unraveling in weak rock masses with low standup times. Early strength shotcrete (1MPa in 1 hour) is an important part of future shotcrete design to allow shotcrete placement early in the drift cycle. This also has important implications for the rapid development from mechanical excavation methods.

9:25 am

Design Considerations and Performance of Carlin Formation Slopes in the Arturo West Button Pit

J. Mattern[1] and N. Rose[2]; [1]Barrick Goldstrike Mine, Elko, NV and [2]Vice President - Geotechnical, Piteau Associates, North Vancouver, BC, Canada

During the past few decades, the Carlin Formation has presented slope design and stability challenges at several mines along the Carlin Trend in northeastern Nevada, with slope "stand-up time" varying from hours to years. Ancient pre-existing landslides, weak lakebed sediments, and altered volcanic ash layers have all played roles. These units have variable lithologic character and can be difficult to model with confidence in 3-dimensions. Laboratory testing has also shown a relatively wide range of material properties, which when added to localized perched and confined groundwater, also affects slope design decisions. Risk based design is therefore a valuable tool, requiring back-analysis results from previous small instabilities and large slope failures. The Arturo West Button Hill Mine is a single cut open pit with a single access through Carlin Formation and a requirement for preserving stable slopes well beyond open pit mine life in order to maintain access to potential underground portals that would be located near the pit bottom. A synopsis of slope stability design inputs, mine design options, and resulting slope performance will be presented.

9:45 am

Newmont's Boddington Open Pit Slope Steepening Program

A. Jack[2], N. Brockhurst[2], F. Basson[3] and J. Lupo[1]; [1]Newmont Mining Corporation, Greenwood Village, CO; [2]Newmont Boddington Gold, Boddington, WA, Australia and [3]Newmont Asia Pacific, Perth, WA, Australia

Newmont's Boddington Mine, located in Western Australia, is an 230,000 tonnes per day open pit and shovel operation. Over the past year, the operation has been trialling a slope steepening program, with the objective to consistently achieve an inter-ramp slope angle of about 61 degrees, while minimizing crest loss and toe flare, and improve overall wall performance. The current trial consists of a triple 12-meter bench (e.g. 36 meter overall bench height), with an average (triple) bench face angle of 85 degrees. The average bench face angle is achieved by mining the first bench to a 75 degree bench face angle; and the second and third benches having a 90 degree bench face angle. Throughout the slope steepening trial, a number of lessons were learned regarding the importance of understanding risks associated with developing steep pit slope walls, structural controls, drilling and blasting techniques on wall performance, communication, and monitoring. This paper presents the results of the slope steepening program, the processes and procedures used during the trial to maintain a safe working environment and the lessons learned.

10:05 am

Slope Performance and Reconciliation at Newmont's Akyem Open Pit

E. Amakye[2], M. Boatemaa[2] and J. Lupo[1]; [1]Newmont Mining Corporation, Greenwood Village, CO and [2]Newmont Golden Ridge Ltd, Accra, Ghana

Newmont's Akyem Mine, located in the Birim North District of Eastern Region in Ghana, is an open pit truck and shovel operation that has been operating for 3 years. The pit slopes for the open pit are being developed through a thick sequence of saprolite soils and saprock, a meta-sediment hanging wall, and a meta-volcanic footwall. In addition, there are a series of graphitic shears that cut through the pit, paralleling the mineralized zone, exposed on the footwall. As with any open pit mine, slope reconciliation is an important aspect of the overall mine operation and its ability to achieve their plan. At the Akyem Mine, slope reconciliation efforts are not only used to support operations, but to evaluate the suitability of the pit slope design with respect to the site conditions. This paper discuss the pit slope performance experienced to-date at the Akyem Mine site and the outcome from the slope reconciliation program. The paper also discusses the difficulties with slope reconciliation and how some of these difficulties were addressed at the operation.

10:25 am

Why the Bingham Canyon Manefay Landslide Failed

B. Ross; 90 Degree Consulting LLC, Tucson, AZ

On April 10th 2013, the Rio Tinto Kennecott's Bingham Canyon Mine experienced the largest highwall failure in mining history when 144 million tons of material fell into the historic pit. This paper, which is based on the new book, Rising to the Occasion – Lessons from the Bingham Canyon Manefay Slide, describes the geologic conditions, sequence of events, and the failure mechanism that led to this gigantic event. This paper will also detail some of the geotechnical monitoring used to predict the failure that was critical in preventing injuries or fatalities.

10:45 am

Geologic Factors in Selecting Rock Bolt Type for Tunnnel Design

A. Schissler; Mining Engineering, Colorado School of Mines, Littleton, CO

Interpreting geologic factors are critical to select the rock bolt type, spacing, and length for tunnel design. The selection must obey the continuum of design which is to assess load demand, compile the design basis, and then to select the rock bolt appliance. The purpose of this paper is to present a design process applied by the author using 3 recent case histories for tunnel design projects in Greenland, Peru, and the United States. The examples utilized will illustrate the design repsonse to load demand in widely varying conditions and results.

11:05 am

Construction of a Seepage Barrier Helps to Improve Water Management and Safety at a Tailings Basin

G. Bryant; Barr Engineering Company, Minneapolis, MN

In the 1990's the Cross Delta Dike was constructed by placing random fill over hydraulically deposited tailings. This 3,500 foot long dike transected the tailings basin as a haul road and to facilitate water management. The dike provided separation between solids storage on the upstream side, and water storage on the downstream side. Operational issues related to seepage, piping development, voids, and dike stability required attention in order to maintain safe operation and efficient water management. As such, a seepage barrier was designed and constructed. Unique characteristics of the tailings and wastewater include high salinity, alkalinity, and sulfates, as well as layers and deposits formed from precipitates. The final design and construction included a composite seepage barrier consisting of a primary soil mix wall using TRD technology and secondary vinyl sheetpile wall within the soil mix. The paper presents the different phases of the project and discusses the various design and construction considerations.

TUESDAY, FEBRUARY 21

MORNING

9:00 am **Room 501**

Mining & Exploration: Management: Mine Cost Estimation and Economic Analysis I

Chair: *S. Stebbins, Aventurine Engineering, Inc.*

9:00 am

Introduction

9:05 am 17-007

All-in Sustaining Cost Analysis: Pros and Cons

T. Camm and A. Yapo; MONTANA TECH, Butte, MT

All-in sustaining cost is a metric used by mining companies to reflect the cost of gold expectation in a consistent format useful to both investors and mining professionals. Cost reporting focused on the direct cost of mining and processing ore was summarized in the non-GAAP cash cost developed by the Gold Institute in 1996. In 2013, a group of mining companies, working with the World Gold Council, developed a more inclusive approach to reporting costs designed to solve the dilemma of showing a more comprehensive reflection of recurring costs involved in producing gold, without discouraging investors.

9:25 am

Acquiring Cost Data for Prefeasibility Studies

B. Terhune; InfoMine USA, CostMine Division, Spokane Valley, WA

The procurement of reliable cost data is an essential step in the development of sound prefeasibility level studies. This paper highlights the differences between prefeasibility and final feasibility mine cost estimating, in terms of accuracy and detail, and how those differences affect cost data requirements. The author details the process of obtaining cost data, including procurement methodologies, time investment, the need for cost data to make engineering sense, and how to approach highly engineered systems. Specific examples are discussed to demonstrate the process. Cost data must be updated on a regular basis to avoid out of date estimates. Finally, the author stresses the importance of networking and personal relationships for successful data acquisition.

9:45 am

Surface Mining Operating Cost Estimation Check Value Using Regression Analysis and Transformation by Known Costs

E. Roe; Gustavson Associates LLC, Lakewood, CO

This study is an update to the regression estimation methodology posited by Camm in Information Circular 9298. Using regression equations derived from Mine Cost Services cost models the surface mining operating cost for

international mines can be predicted with some accuracy. The regression equation must be transformed by a known cost value from a mine using a mining method similar to the mine being estimated. Stripping ratio and production rate does not have to be similar. This study examines actual surface mining operating costs as compared to the costs predicted by technical studies prior to mine production and the value estimated from a transformed regression equation.

10:05 am

MAFMINE: a Cost Estimator Tool for Quick Evaluation

C. Petter[1], R. D'Arrigo[1], G. Scheffer[1], R. Petter[1], L. Wives[1] and M. Armstrong[2]; [1]UFRGS, Porto Alegre, Brazil and [2]Economy, Fundação Getúlio Vargas, Rio de Janeiro, Rio de Janeiro, Brazil

There are many methods to estimate costs in a quick way. One of these methods is the Parametric Method, where costs are derived from general algorithms (or curves). In the early 80's, T. Alan O'Hara developed parametrical models to estimate costs in mining. Derived from an original tool based on the O'Hara model, done by the Ecole des Mines de Paris in the 90's, a software called MAFMINE is on the way of development. The O'Hara Model, as well as other existing models, is based on foreign economies. There is no mining cost model using or based in Brazilian data, so because of this, the so-called burgernomics was tested as an adjustment factor when considering all the structural peculiarities when investing in Brazil. The MAFMINE software itself involved the use of a computer model known as client-server. Client-server is a computational model which separates clients and server which are usually interconnected using a computer network. MAFMINE generates an order of magnitude for CAPEX and OPEX to establish a very first Discounted Cash Flow (DCF) in a mining venture. For quick evaluations, in a business plan level, the results are very promising.

10:25 am

The Progression of Mine Operating Cost Estimation for the Newmont Mining Corp-Ahafo North Project

C. Weber; Techncial Services, Newmont Mining Corp, Greenwood Village, CO

This presentation will discuss the Ahafo North Project, located in South Central Ghana, approximately 30 km north of Newmont's Ahafo South operating mine. The author has been involved since 2012 with several studies following Newmont's Stage Gate process. The methods for mine operating cost estimating, including benchmarking, development of costs through first principles, independent reviews, cost estimate range assessments and incorporating new information as the project moved through scoping, pre-feasibility and feasibility study will be discussed.

10:45 am

Case Study: Financial Evaluation of Free-Digging versus Drilling and Blasting

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

This study describes the field testing and first-pass financial evaluation used to compare free-digging to drilling and blasting at a cement raw material quarry. The quarry currently uses two 230 plus tonne excavators and a 230 tonne face shovel to excavate 1.5 million tonnes of raw materials per year. Two of the three kits must be replaced in the next two years, amounting to significant capital expenditures. As such, the operation decided to evaluate an alternative extraction method using drilling and blasting and excavating with a smaller 90 tonne wheel loader or 70 tonne excavator. The study required a full load and haul fleet study, drill and blast trial evaluation, and financial comparison. This presentation focuses on the financial model evaluation, which takes into account the results of six weeks of field work required to fully characterize each mining option.

11:05 am
Early-Stage Open Pit Cost Estimation
D. Tutton; Consultant Mining Engineer, Dierdorf, Germany

Cost curves proved invaluable in early-stage estimation of mining costs when mining inflation was at a low level. Their use was well documented by O'Hara, Camm and the USBM. From about 2003, inflation of mining costs and their subsequent deflation have made the use of cost curves unreliable. In addition, cost variability by location has impacted result accuracy. In this paper, the use of consumption curves and their modification to cost estimates based on local price bundles are presented as an alternative approach for the estimation of open pit capital and operating costs. Results of consumption-curve analysis are benchmarked against underlying first principles cost estimates and show good calibration. It is therefore proposed that the consumption-curve approach provides a good basis for early-stage cost estimation.

TUESDAY, FEBRUARY 21
MORNING

9:00 am **Room 504**
Mining & Exploration: Operations: Continuous Improvement in Underground Operations
Sponsored by thyssenkrupp Industrial Solutions

Chairs: *J. Rahn, Newmont, Elko, NV*
G.Wilson, Mine Engineer - Barrick Goldstrike Mines Inc.

9:00 am
Introduction

9:05 am
Relationships Between Recovery Factor and Operational Ore Loss: Risks Related to the Interpretation of Stope Technical Performance
S. Ibarra-Gutiérrez, M. Laflamme and S. Planeta; Université Laval, Quebec City, QC, Canada

The mine recovery factor corresponds to the ratio between the amount of ore which has been effectively extracted from a stope, and the total amount contained inside the planned stope boundaries. Mostly associated to ore loss, this factor is used in the industry as a key player in the evaluation of stope technical performance. Such an evaluation is critical to mines where the open stope method is used, not only because it enforces stope boundary control and keeping track of the stability, but also because the conversion of mineral resources into reserves will determine the economic viability of any project, in accordance with Canada's NI 43-101, as pertaining to information on mining projects. Nevertheless, some voids have been detected in the literature regarding the effectiveness of ore loss being the only parameter used to calculate a recovery factor, which could lead to a misinterpretation of technical performance. This article shows that said performance described in terms of a recovery factor might underestimate actual ore loss. Mining companies are welcomed to reflect on how they could benefit from complete and precise information.

9:25 am

Mine Power Quality

J. Fisher; Stantec, Tempe, AZ

Large modern underground mines produce and transport huge quantities of rock, which is a logistical marvel. To do so, electricity is used in drilling, blasting, ventilation, refrigeration, heating, pumping, conveying, hoisting, transportation, communications, and controls. Since most mines are remote from large support infrastructure, basic utilities require thorough upfront consideration. An exploration drilling program may require minimal camp infrastructure and electrical support, but a large underground mine will require significant utility power. Providing power distribution to meet development and production demands with redundancy, suitable power quality, and appropriate life safety measures can be challenging; similarly, communications and control systems have complex requirements. Maintaining production while safely minimizing workforce and maximizing efficiency requires control and management of all systems. This has to work cost effectively and reliably—poor power quality can disrupt production. This paper overviews the electrical systems in complex underground mines, their interactions, the resulting power quality issues, and the associated mitigations.

9:45 am

Optimization of Underground Dewatering and Depressurization of an Open Pit

C. Shaw; Underground Mining Engineering, Rio Tinto, Saratoga Springs, UT

Rio Tinto has designed and constructed underground depressurization / dewatering galleries to improve slope stability of the Open-Pit mine. The drainage galleries utilize hundreds of drains drilled in all orientations including from vertical and +45° up through -45° down. Pumping wells with orientations between -70° and -90° are also drilled with larger diameters to accommodate pumps. Initial designs were optimized mid-construction to increase safety, improve performance, improve schedule and decrease cost. Optimization was based on depressurization targets using analysis and interpretation of the dominant fault and fracture network. Drain holes were specifically oriented to enhance the intersection of the fracture network using stereonet analysis of the pertinent fracture networks. The hypothesis was to use fracture intersections for increased flows and greater depressurization of the Open-Pit highwall. Underground drill stations were then designed around the depressurization targets and alignments of the drain holes. The optimization has resulted in significant improvement in costs, drilling methodologies, increased flows, and better responses in the Open-Pit mine piezometers.

10:05 am

Business Excellence in Underground Mining Cycle: a Case Study

A. Rai; Chief Engineer, Technical Services, Barrick Turquoise Ridge Inc, Winnemucca, NV

Last decade, Underground Mining Operations has experienced significant challenges to maintain or improve productivity with current operating practices. Continuous mining cycle is the key to engage front lead supervisor with a track record on effective use of process controls. Turquoise Ridge performed a study to understand significant opportunity loss of ore to waste leading to minimum 1000-1200 ounces per month loss to the site (Jan-March 2015). The culture change and functional controls were identified as challenges that left all department experience (internal and external customer) dissatisfaction. The paper discusses a black belt sixsigma approach with the initiatives the operations took to continue the drive to develop an in-house Ore Loss & Dilution assessment process. The team improved site ROI (approximately $7.2 M in year 1) with Muck Routing, Muck Handling Process, and Delivery to end-user matrix.

10:25 am

Production Driver Tree - Tool for Finding Value Quick

R. Robison; Breakthrough Mining Services, LLC, Wildwood, MO

After safety, many mining operations focus on production - output. Output is like the score on a sports scoreboard. The score lets you know if you are winning or losing but conveys nothing about what is possible or what needs to be improved. Mining output is simply defined as dig time multiplied by dig rate. A deeper understanding is started by expanding the elements of dig time and dig rate into a “tree” of production drivers. Dig time is usually the best place to start a Production Tree Model because there are always opportunities for change. Elements of dig time include scheduled time, startup time, sources of downtime and mine design. Dig rate is usually more difficult to change. Equipment selection defines the potential dig rate. Operator skill and geologic conditions de-rate potential dig rates. Each of these elements can be broken down further. The financial impact of a change can be estimated using the incremental variable cost margin. A Production Tree Model is a powerful tool to visualize, identify and quantify improvement opportunities quickly. Understanding and managing the drivers will insure a winning scoreboard.

10:45 am

Evolution in Roof Bolting Machine Technology

B. Ballamudi and Z. Hyder; Mining, Missouri S&T, Rolla, MO

The safe and optimal installation of roof bolts remains one of the biggest challenges mining industry is still facing. Moving from the traditional hand-held drilling to mechanized bolting is one radical leap in removing the operator from unsafe to relatively safer conditions. Statistically speaking the injuries recorded in 1970s were hovering around 300 as opposed to the recent trend at less than 50 injuries being reported. In spite of advancements, the handling of drill steel itself, and inserting resin cartridges and bolts remains one of the most hazardous tasks and is a major cause of injuries to mineworkers. Fletcher, being the pioneer in mechanized bolting, has proven its mettle by improving the safety of procedure. Sandvik, following closely behind Fletcher, has made equally good progress in roof bolting technology. This paper presents an insight into the strides of advancement made in the roof bolting technology, its current applications and status, and the future developments in store. The paper aims to identify the customer needs and future developments keeping in view the safety of the workers, removing hazards associated with the operation and increased productivity.

11:05 am
Deploying an Underground Production and Safety Tracking System Using the Internet of Things, Gamification, and Mobile Apps in Various Cultures
S. Dessureault; MISOM Tech / U. of Az, Tucson, AZ

The advent of low-cost technologies such as the Internet of Things (IoT) and Mobile apps has created the opportunity to bring automated production and safety tracking to mines of any size. Underground mines in particular, have typically had limited visibility, due to limited location tracking, expense of wireless connectivity, and the larger number of machines and personnel needed to be tracked. Several recent innovations in technology and then deployments of innovative IoT nearables for tracking cycles, even sequences automatically, locating personnel, as well as collecting digital safety and maintenance forms, has shown that technology cost is no longer a challenge to overcome. Suddenly, these mines have large quantities of digital data, and will be faced with the same problem faced by larger mines: underutilization of data. However, a new approach (new to mining) to using data can also be brought to bear: gamification, which is an approach to having users engage with the data in a more addictive and focused manner. Several case studies will be analyzed, showing how gamification can be adjusted to different cultures.

TUESDAY, FEBRUARY 21
MORNING

9:00 am Room 505
Mining & Exploration: Operations: Innovative Information Mining & Big Data

Chair: *L. Walker, Freeport McMoRan Inc, Morenci, AZ*

9:00 am
Introduction

9:05 am
Old Trucks, New Ideas: Adding Value to Aging Assets
B. Brown; Freeport McMoRan Inc, Silver City, NM

Present day mining equipment is extremely state-of-the-art. Highly technical modern marvels using numerous complicated onboard computer systems process, communicate & manage large amounts of information needed to do business in the modern era. Along with all the latest bells & whistles, they are exceedingly expensive. One could easily reach a conclusion that older equipment is simply not up to the challenge. In this presentation we examine the successful long-term utilization of older large off-highway trucks through the development of up-to-date technologies, including RAMP® (Remote Asset Monitoring Process™) & ultramodern Big Data practices.

9:25 am

A Journey towards Mine to Port Operational Intelligence

O. Bascur[1], M. Plourde[2], D. Gervais[1], S. Paquet[2] and S. Morissette[2]; [1]OSIsoft, LLC., Houston, TX and [2]IT, ArcelorMittal Mining, Port Cartier, QC, Canada

Michel Plourde, Stephan Paquet, Sophie Morissette affiliated to ArcelorMittal Mining, Canada ArcelorMittal Mines Canada is one of the premier Canadian suppliers of iron-ore to world steel markets. ArcelorMittal has diverse, geographically dispersed operations, including an open pit mine at Mont-Wright near the town of Fermont in Quebec, Canada, a pellet plant and a private port in Port-Cartier, Quebec as well as a 420 km railway linking both sites. When logistical issues have cropped up throughout its supply chain, ArcelorMittal started using their real time data infrastructure to transform and correlate data from disparate key systems to produce information enabling strategic and rapid decision making. Creating value in cyclical environment is the key. As the cornerstone for transforming data into action. This presentation describes how Arcelor Mittal uses real time data and asset framework analysis tools to optimize operations and logistics to avoid production and equipment losses across their Mining and Mineral processing complex. It emphasizes the need to have data and events to monetize major and minor losses using the latest data analytics tools.

9:45 am

Identifying Opportunities for Mining and Processing Value Improvement Though Blast Movement Modelling

E. Sellers and S. Kanchibotla; JKTech, Brisbane, QLD, Australia

The objective of mining to maximise output and minimise costs becomes a complicated optimisation involving resource variability, mining and processing methods and implementation quality. Generally there is a good understanding of the cost – benefit within each department. New advances in big data analytics have improved loading, trucking and processing operations. However, the missing link in operational improvement is quantifying what happened to the rock between the blast and the excavation and the mixed rock mass actually presents to the mill. If the correct material is not identified, correctly blended and sent to the mill at the right time then there is the potential loss of value from reduced throughput and metal. The key to further improvement is modelling the time dependent production of value. A numerical model of blasting has been built that associates the blast energy with the 3D distribution of geological, processability and blastability parameters. The final muckpile can be excavated in any sequence to identify the optimal sequence for processing. The paper will demonstrate the value using case studies from a number of mining operations.

10:05 am

Business Intelligence and Mining: Implementation Issues and Propositions to Address Them

G. Neill and D. Wells; Wenco International Mining Systems, Seattle, WA

The capacity for extensive data collection has transformed many industries in recent years, including mining. Yet, this wealth of data presents a new challenge: how to make sense of it. While industries such as retail have successfully incorporated off-the-shelf business intelligence platforms, mining has struggled. Historically, these solutions have proved ineffective at handling the types of data required for mining analytics, such as the large degree of geospatial records. Likewise, visualization components of these solutions lacked turnkey dashboards practical for mining, particularly in terms of mapping and location reporting. Custom configuration of these systems greatly increased their demand on resources and added a further barrier to their implementation. This paper discusses the issues interfering with the adoption of business intelligence by the mining industry. Then, it proposes parameters for a mining-specific solution designed to reduce configuration time, demands on technical support, and logistical hurdles involved with integrating business intelligence into mining.

10:25 am

Investing in Data to Reduce Maintenance Spend

M. Atkins; Institute of Management Consulting, Houston, TX

The cost of maintaining assets represents a large portion of the OPEX budget so identifying ways to optimize productivity for the least spend and reduce maintenance costs is a perennial goal for most operations. This presentation describes how a number of large multinational mining companies independently recently implemented similar approaches to enhance their Asset Management data to enable identification of opportunities to reduce maintenance spend. We will walk through the data enrichment process, from the recognition that there are often limitations with existing systems data, through to the development of an Enterprise wide Data Warehouse from which meaningful insights can be extracted. We will describe in pragmatic terms the scalable approach essential for the successful design and implementation of a broad based enterprise wide information repository which can then be used for a variety of purposes including Value Chain (Pit to Port) visualization, role specific KPI dash boards and Data Analytics; identifying, for example, opportunities for optimizing processing plant throughput, reducing mobile fleet maintenance materials costs and rationalizing supply chain inventory.

10:45 am

Data for Dollars – Turning Data into Real Business Value in Mining

b. winters; Marketing, Honeywell, Phoenix, AZ

With all of the press and focus on Industrial Internet of Things (IIoT) and Big Data some are left wondering what it means while others are rapidly harnessing the power. While the underlying capabilities and technologies have been around for some time the actual strategies and approaches to derive value will explored in this paper and how the top players in the space are deploying techniques for intelligent data collection, edge analytics, data management and aggregation strategies to transform the data actionable information and turning the hype into real business value.

11:05 am
Geospatial Mapping and Surveying Robotics for Both GPS and GPS Denied Environments
G. Baiden; Penguin Automated Systems Inc., Naughton, ON, Canada

The introduction of GPS systems to surface mining have resulted in significant positive changes to open pit mining techniques. The next step in this trend has been to find a way to achieve the differential GPS results for underground mining (GPS denied environments). The achievement of this result would see a similar paradigm result for underground mining quality, mining machine control, rock mechanics and ventilation analysis amongst many more. Our team has researched this process and achieved a high quality equivalent point over the last several years and we are now able to report that a comparable result, a few centimeters of accuracy, has been achieved for underground mining in terms of mapping and positioning. The system based on a sensor and software suite has demonstrated this result in actual underground testing and the transition testing between surface and underground. This paper will describe the technology application, the results achieved to date and the potential future uses of the technology for mining, civil construction and oil and gas.

TUESDAY, FEBRUARY 21
MORNING

9:00 am **Room 503**
Mining & Exploration: Operations: New and Expansion Surface Operations Overview
Sponsored by thyssenkrupp Industrial Solutions

Chair: *P. Haarala, Barrick Goldstrike Mines, Inc., Elko, NV*

9:00 am
Introduction

9:05 am
Open Pit, Underground, or Both? New Exploration Model Unlocking Value at the McCoy-Cove Project Chad E. Peters Premier Gold Mines, Ltd., Battle Mountain, NV
C. Peters; Exploration, Premier Gold Mines Limited, Winnemucca, NV

The McCoy-Cove Project is located 35 miles south of Battle Mountain in Lander County, Nevada, along the prolific Battle Mountain-Eureka gold trend. Echo Bay Mines Ltd. conducted open pit and underground mining at McCoy-Cove from 1986 to 2001, producing 3.3 million ounces Au and 110+ million ounces Ag. Premier acquired 100% of the property by September 2014 and a renewed focus on the Helen zone in early 2016 led to an extensive remodeling effort and subsequent reinterpretation of both the Helen and CSD zones as thrust fault-hosted Carlin-style deposits. Recent confirmation drilling has validated the new structural model and identified the Carlin-style CSD Gap target located between the Helen and CSD zones. Early drilling in the CSD Gap indicates significant potential to further expand high-grade mineralization and connect the Helen and CSD zones into one continuous deposit, which may be amenable to a combination of open pit and underground mining methods. Future activity will include a property-wide mineral resource update in early 2017, as well as continued permitting, engineering and metallurgy activities with the goal of potentially re-establishing mine production at McCoy-Cove.

9:25 am

Donlin Gold Project: Development Plans and Permitting Update

C. Krall; NOVAGOLD RESOURCES, Salt Lake City, UT

Donlin Gold is an open pit gold development project located in southwestern Alaska, equally owned by both NOVAGOLD RESOURCES Inc. and Barrick Gold US, Inc. in a 50/50 joint partnership. With 39 million ounces of contained gold in measured and indicated mineral resources and a planned production profile averaging over one million ounces per year over 27 years, Donlin Gold is one of the world's largest undeveloped gold deposits. In mid-2012, the owners and project team formally commenced permitting under the NEPA process. In late 2015, the draft EIS was published by the lead permitting agency, the U.S. Army Corps of Engineers, for public comment. The owners and project team continue to support the completion of the final EIS, as well as other permits required to build and operate the project. This presentation will discuss the history of the Donlin Gold project, the construction and operation plans as envisioned in the latest feasibility study, and an update on the permitting progress.

9:45 am

Mining Excellence at Barrick Cortez - the Evolution of Open Pit Mine Planning at Cortez Hills

C. Cavasin; SME, Crescent Valley, NV

This session will review the evolution of open pit mine planning at Cortez. Starting from the history of how plans were previously done from short, medium, and long range perspectives to how they are now integrated together with links to maintenance, operations, process, and accounting. The presentation will also cover how we leveraging digital solutions to improve plan communications, execution, and reporting.

TUESDAY, FEBRUARY 21

MORNING

9:00 am **Room 709**

MPD: Flotation of Rare Earth Minerals

Chairs: *T. Bhambhani, Cytec Industries Inc., Stamford, CT*
D. Laney, Newmont Mining Corp, Elko, NV

9:00 am

Introduction

9:05 am

Froth Flotation Performance of Novel Collectors for Rare Earth Minerals

R. LaDouceur, A. Aasved and C. Young; Metallurgy, Montana Tech, Butte, MT

The lanthanides are more commonly referred to as rare earth elements (REEs). Because of molecular similarities in their f-shell orbitals, REE-bearing minerals usually vary in their compositions as solid solutions. Those similarities also make separation of individual lanthanide elements difficult. In this regard, bulk separations into concentrates are normally done first. Techniques, such as flotation, are utilized to separate REE-minerals from invaluable gangue in a slurry. Flotation is a complex process that works based on differences in hydrophobic minerals. It involves many variables broadly ranging from surface chemistry to energy input parameters. Collectors are surfactants that adsorb at mineral surfaces and modify them to induce hydrophobicity. In this study, flotation experiments were performed for three novel collectors by varying both collector dosage and pH. Zeta potential vs. pH measurements were used to elucidate the conditions for flotation of a synthetic rare earth oxide. Parametric models were created for the flotation experiments to determine maximum grade and recovery for each of the novel collectors.

9:25 am

Wetting Behavior of Rare Earth Minerals in the Presence of Ionic Liquids and Polymers

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

The efficiency of separation of valuable minerals by froth flotation depends strongly on the interaction between mineral surface and water molecules as well as wetting characteristics of different mineral surfaces. The contact angle value is a predominant factor to quantify the wettability and assess the interaction between mineral surface and water molecules. Several surfactants and chemicals have been employed to modify the wetting behavior of minerals by adsorption of ions on the solid-liquid interface. Since the properties of ionic liquids (ILs) can be customized and adjusted by selecting appropriate ions, they are good options to be used as suitable surfactants to modify the surface properties at the solid-liquid interface. This study investigated the efficiency of ionic liquids and polymers on the wettability of rare earth minerals. The contact angle value was used to quantify the hydrophobic characteristics of the rare earth mineral surface in the presence of ionic liquids, polymers, and conventional collectors. It is believed that the floatability of rare earth minerals can be enhanced by tailoring the ionic liquids and polymers to different rare earth minerals.

9:45 am

Synthesis and Characterization of the Rare Earth Collector N,3-dihydroxy-2-naphthamide

R. LaDouceur, B. Suslavich and C. Young; Metallurgy, Montana Tech, Butte, MT

Rare earth elements (REEs) play a critical role in modern materials including but not limited to electronics, magnetics and optics. However, their processing and extraction is first dependent on the concentration of REE- bearing minerals from ores and then their selective separation into individual REEs. Collectors are chemicals which modify mineral surfaces so that they may be selectively extracted from a slurry. Studies have shown that hydroxamic acid-based collectors are selective to REE-bearing minerals. One example is N,3-dihydroxy-2-naphthamide which is colloquially known as H205 and has

been thoroughly examined by the Baotou Research Institute for Rare Earths (BRIRE) in China. Unfortunately, no characteristic data nor a documented synthesis route of this proprietary collector are available. In this study, several synthetic approaches were taken to create this compound. Furthermore, important structural and characteristic data was gathered such as the pKa's of the compound, preferred structural conformers, and adsorption to REE oxides. With this information, optimal conditions for the flotation of REE-bearing minerals were determined.

10:05 am

Studies on the Nature of Hydroxamate Complexation on the Surface of Neodymium Oxide

M. Sime, C. Young, A. Das and G. Hope; Metallurgical and Materials Engineering, Montana Tech, the University of Montana, Butte, MT

Adsorption of different concentrations of salicyl hydroxamic acid (SHA) on neodymium oxide surface was studied. The adsorbed surfaces were examined using Laser Raman Spectroscopy (LRS) to verify the presence of the chelation compound. Precipitates of Nd-compound were produced under different SHA concentrations and subjected to X-Ray diffraction (XRD) and LRS analysis. XRD results established that significant hydroxide formation takes place. However, hydroxamate complexation increased with increasing SHA concentration. Peaks from the C-H stretching band and C=N vibration bands were identified and areas under the peaks were quantified. Formation of the hydroxamate compound was ascertained from the C=N bands around 1597 cm-1. The area under the aromatic C-H peaks around 3062 cm-1 established that the extent of hydroxamate complexation increased with increasing SHA concentration. It was concluded that the chelation occurs through chemical bonding between the SHA anion and the trivalent Nd cation upon which the hydroxamate complex precipitates at the surface. The hydroxamate complex of Nd was synthesized and compared to verify the complexation behavior.

10:25 am 17-126

Concentration of Rare Earth Minerals from Coal by Froth Flotation

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

Rare earth elements (REEs) found in coal are in the form of minerals, ion-substitution with clays and organic affinity. Rare earth minerals (REMs) such as monazite exist in coal and have a grain size less than 5 microns. Froth flotation was successful in concentrating REMs existing in a thickener underflow material derived from Fire Clay seam coal which contained around 300 ppm of rare earth elements (REEs). Conditioning with fatty acid followed by processing using multiple stages of conventional flotation produced a final concentrate containing 2300 ppm REEs. Using a laboratory flotation column, a concentrate with more than 5000 ppm REEs was produced while recovering 30% of the REEs.

10:45 am

Flotation Chemistry Considerations in the Selective Flotation of Bastnaesite with Alkyl Phosphate Collectors

W. Liu, X. Wang and J. Miller; Metallurgical Engineering, University of Utah, Salt Lake City, UT

Little attention has been given to the use of lauryl phosphate as a collector for the selective flotation of bastnaesite from calcite and/or quartz. Recent results from captive bubble contact angle measurements, zeta potential measurements, micro-flotation experiments and universal force field calculations for bastnaesite, calcite and quartz indicate that better selectivity for bastnaesite is achieved using potassium lauryl phosphate when compared with the selectivity using octyl hydroxamate as collector. These results suggest that potassium lauryl phosphate might be a promising collector in the flotation of bastnaesite ores.

11:05 am

Fundamental Study of the Hydroxamic Acid Adsorption on Monazite

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

Hydroxamic acid is a common flotation collector with strong affinity and high selectivity. The adsorption mechanism of hydroxamic acid on monazite was studied using kinetic, isotherm, and thermodynamic adsorption tests as well as FTIR, titration and micro-flotation tests. The adsorption was determined to occur due to a chemisorption/surface reaction/surface precipitation process. At low hydroxamic acid concentrations, the initial stage of adsorption was by the reaction between surface active sites and hydroxamic acid molecules (chemisorption). With an increase in concentration and interaction time, surface active sites were removed from their lattice sites and surface reaction became predominant. For both chemisorption and surface reaction, adsorption was an exothermic and entropy driven process. Maximum adsorption was achieved at pH 9.0. However, a strong basic and higher temperature environment contributes to surface precipitation of basic rare earth hydroxamate.

11:25 am **17-052**

Electrokinetic and Flotation Behaviors of Ilmenite in the Presence of Lead Ions Using Sodium Oleate as the Collector

P. Chen, J. Zhai, W. Sun, Y. Hu and Z. Yin; School of mineral processing and bioengineering, Central South University, Changsha, China

The electrokinetic and flotation behaviors of ilmenite using lead ions as the activator and sodium oleate as the collector were studied. The results of microflotation show that the flotability of ilmenite can be improved by lead ions obviously. The isoelectric point of ilmenite increases from 5.32 to 7.7 after the addition of lead ions because of the adsorption of Pb^{2+} and $Pb(OH)^{+}$. The results of zeta potential measurements and the collector adsorption density calculation show that the adsorption of sodium oleate on the ilmenite surface via chemisorptions in addition to electrostatic interactions. Besides, the adsorption density calculation results show that as the addition of lead ions as the activator, the adsorption amounts of collector are greater than those without activation which is in aggrement with the flotation behaviors.

TUESDAY, FEBRUARY 21

MORNING

9:00 am **Room 703**

MPD: Leaching

Chairs: *J. Lee, University of Arizona, Tucson, AZ*
K. Garcia, Freeport McMoRan
B. Burrell, Freeport-McMoRan, Safford, AZ

9:00 am

Introduction

9:05 am

Heap Leach Modeling – Strategic Approaches for Metal Production Forecasting

J. Marsden[1] and M. Botz[2]; [1]John O Marsden LLC, Phoenix, AZ and [2]Elbow Creek Engineering, Bozeman, MT

Heap leaching is responsible for approximately 21% (3.9 M metric tonnes) of copper production and 9% (270 tonnes or 8.7 M oz) of gold production worldwide. Given metal price assumptions of $2.25/lb Cu and $1,250/oz Au, these portions of global production generate revenues of US$19 billion and US$11 billion, respectively. For heap leaching operations, variances in actual metal production from budgetary forecast estimates can mean the difference between success (value creation) and failure (value destruction) for a heap leach project. There are no clear standards or guidelines for developing heap leach metal production forecasts. There are a variety of different modeling approaches that can be utilized for this purpose, however, these vary in cost, complexity, time to implement, accuracy and credibility. This paper explores the options available for heap leach modeling, discusses the advantages and disadvantages of each approach, and provides guidelines/recommendations for an effective approach to modeling metal production at existing or planned heap leach operations. The paper also provides expected ranges of variation between actual metal production and modeled production.

9:25 am **17-047**

Dynamic Simulation of Precious Metal Recovery from a Valley-Fill Heap Leach Facility

J. Bilant[2], G. Robinson[2], B. Robles[2] and J. Donnelly[1]; [1]Hatch, Fort Collins, CO and [2]Coeur Mining, Inc., Lovelock, NV

A spatially-discretized heap leach simulation model was developed within the GoldSim™ modeling framework for the Coeur Rochester Mine, Nevada. The model is being evaluated by Rochester as a means of improving forecasting of silver and gold production on an actively loaded valley fill heap leach facility. Optimization of future heap leach operations and crusher product size is also being evaluated with this software. Simulation modeling incorporates metallurgical data such as mine planning, particle size distribution of placed ore, stacking plans, pad geometry, and leaching dynamics.

The heap leach model is represented as a discretized matrix with lifts providing vertical separation to form 19,840 spatially discrete cells. Each cell is quantified with regard to ore properties and metal content. The model tracks solution and cyanide-complexed silver and gold within each cell as a function of time based on pad operations, unsaturated flow properties, and kinetic rates. Practical heap leach management and daily operation will be discussed as it relates to the simulation and forecasting model.

9:45 am

Advances in Scale Control Modeling - Where Chemistry Meets the Digital Age

R. Davis[1], N. Zwaneveld[2] and R. Arndt[2]; [1]Mining Research, Nalco Water, Naperville, IL and [2]Mining Marketing, Nalco Water, Naperville, IL

This presentation will introduce the new Nalco Mining Optimizer, a comprehensive tool for predicting the scale stress of mine process waters and for troubleshooting mine water issues. The Nalco Mining Optimizer is a scale modeling and treatment recommendation program which is a step change project that overcame problems with existing models. A new Mining Industry platform was built specifically to overcome incorrect handling of pH and alkalinity, the addition of common mining reagents and the difficulty of modeling complex water blends. The presentation will describe the current state of the art in scale formation modeling, the mechanisms of scale formation and scale inhibition, and the unique challenges which must be overcome in the modeling of mining waters.

10:05 am

Implementation of Automated Raffinate Flushing

J. Nunley and C. Wooten; Safford Mine, Freeport-McMoRan, Safford, AZ

Freeport-McMoRan's Safford Mine recently implemented a system of automated flush valves for daily flushing of each module on their crushed ore heap leach stockpile. Combined with Safford's existing pressure and flow monitoring systems, these fully automated, radio-controlled valves provide an enhanced level of real-time control of the leach pad. The system allows for more consistent flushing and more flexibility in flushing schedules, and can also be utilized to proactively react to SX plant upsets and increased turbidity events, by increasing flushing without a substantial manpower commitment. Since it's commissioning in Q1 2016 this system has supported decreased plugging, decreased raffinate flow variability, and provided a substantial reduction in contracted labor costs. This presentation will describe the fundamental components and workings of the system, cover some of the lessons learned during installation and commissioning, highlight the substantial benefits that have been realized, and discuss additional future opportunities.

10:25 am

The Toowong Process: Viable Removal of Arsenic, Antimony and other Deleterious Elements from Base Metal Concentrates Using a Novel Alkaline Leaching Process

P. Rohner, D. Turner and L. MacDonald; Core Resources, Albion, QLD, Australia

Increasing levels of arsenic in base metals concentrates, together with tightening restrictions on the trading of high arsenic concentrates, are posing a substantial risk to the global base metals industry. Outside of blending the industry still lacks a widely adopted solution to this problem. The Toowong

Process is an atmospheric alkaline leaching technology for the removal of arsenic, antimony and other elements from base metal concentrates, and antimony from gold concentrates. The process significantly reduces operating costs compared to existing alkaline leaching technologies by reducing/eliminating use of sulphide reagent, and process recycling of other reagents. The Toowong Process was conceptualised in 2010 as part of the development of the Tampakan project. A patent application was lodged for the technology in 2011, followed by a 34 day continuous integrated pilot plant operation in 2012. Arsenic reduction to <0.1% from feeds of 1.1% As were demonstrated at steady state in two extended pilot plant campaigns The current paper reviews the process chemistry and results of the pilot plant trials. An techno-economic evaluation is also made comparing to existing technologies.

10:45 am

Recycling of Electric Vehicles Lithium-Ion Batteries by Physical and Hydrometallugical Process

H. Kim[1], K. Yi[1], J. Ahn[3], j. Sohn[2] and k. lee[1]; [1]SungeelHiTech, Gunsan-si, Korea (the Republic of); [2]KIGAM, DaeJeon, Korea (the Republic of) and [3]Daejin University, Pocheon, Korea (the Republic of)

Recently, the use of the EV(Electric Vehicles) has been explosively increased. EV-LIBs (Electric Vehicles Lithium-ion batteries) not only contain valuable metals but also consist of large metal-containing hazardous waste. The spent lithium-ion battery pack(227 kg) is made of 12 modules which are composed of 11 cells. This pack was dismantled manually in the dismantling line which is composed of lift, conveyor belt and hood system with the dismantling capacity of 50 packs/day. After dismantling, cells are mechanically crushed and separated. The result crushing and separation showed that over 95% of valuable metals. Through reductive leaching with H2O2 and H2SO4, leaching efficiency of valuable metals. After removing some impurities such as Cu, Al, and Fe the leaching solutions containing Co, Mn, Ni, and Li could be utilized for the source material of Li-ion battery. Continuous separation using mixer-settler have been established to separate Co and Ni from leached Co/Ni/Li solutions by Na-PC88A and Na-D2EHPA dissolved in Exxol D80 at SungEel HiTech Co. Ltd. in Korea.

11:05 am

Hydrometallurgical Recovery of Rare Earth Elements from Coal Sources

X. Yang[1], R. Honaker[1] and K. Han[2]; [1]Mining Engineering, University of Kentucky, Lexington, KY and [2]South Dakota School of Mines, Rapid City, SD

An extensive test program was conducted to evaluate the ability to recover rare earth elements (REEs) from pre-combusted coal sources by ion exchange and leaching. The tests involved coal samples collected from three coal preparation plants operating in different basins. In each case, the leachability of the REEs was found to be significantly better for the material within the specific gravity fraction of around 1.6 to 2.0 (i.e., middlings) as opposed to the total coarse reject and thickener underflow streams. The recovery of REEs was limited to around 10% when using ammonium sulfate at pH 5 with preferential recovery of the heavy REEs. However, when using 1 mol/L of nitric acid, nearly 85% recovery of the REEs was extracted from the middlings of Fire Clay seam coal. For Kentucky No. 13 middlings material collected in the Illinois basin, 60% of the total REEs was recovered under the same leaching conditions. Effects of acid concentration, solids concentration, retention time, leaching temperature, and particle size on REE leaching efficiency were fully examined and discussed in the paper.

TUESDAY, FEBRUARY 21

MORNING

9:00 am **Room 705**

MPD: Physical Separations

Chairs: *T. Rauch, Jacobs, Venetia, PA*
D. Perkins, Derrick Engineering, Buffalo, NY

9:00 am

Introduction

9:05 am

Selective Comminution for Indium Beneficiation from Waste LCD Screens

T. Boundy, M. Boyton and P. Taylor; Colorado School of Mines, Golden, CO

More than three quarters of global indium consumption is used for the manufacture of liquid crystal displays (LCDs). These devices contain indium at concentrations that appear to be too low to be economically valorized by standard hydro- or pyrometallurgical methods under current market conditions. Because indium is a metal critical to many electronics and clean energy technologies, developing commercially viable processes for recovery indium from such end of life products is expected to offer societal benefit. While LCD screens contain indium at low levels, the surface confinement of indium in these devices makes abrasion an intriguing option for concentrating indium to industrially relevant levels. To that end, attrition scrubbing is investigated and shown capable of producing a concentrate upgraded in indium concentration by a factor of 10 with greater than 90% recovery of indium. The same process leaves the LCD glass cleaned of semiconductor elements that are viewed as impurities to the glass recycling sector.

9:25 am **17-012**

Applications of Automatic Sensor Based Sorting to Mining Ores

A. Young[1], M. Veras[2], C. Petter[1], D. Neto[3] and C. Sampaio[1]; [1]Departamento de Engenharia de Minas, Metalurgia, e Sciencâs de Materiais, Universidade Federal do Rio Grande do Sul (UFRGS), Porto Alegre, Rio Grande do Sul, Brazil; [2]Departamento de Engenharia de Minas, Metalurgia, e Sciencâs de Materiais, Universidade Federal do Rio Grande do Sul (UFRGS), Federal Institute of Amapá (IFAP), Porto Alegre/Amapá, Brazil and [3]EPUSP, São Paulo, São Paulo, Brazil

Due to new technological advancements, automatic sensor based sorting has made progress within industrial minerals, precious metals, diamond, and coal mining in recent years. In order to re-introduce the technology to other mining sectors, this research discusses its application to Iron, Manganese, and Zinc ores through test works carried out by the authors. These test works were performed using a laboratory scale automatic sorter equiped with Dual Energy X-ray Transmission (DE-XRT) sensor technology. Separation of the material was performed by use of mechanical flap and

ore particles were fed one at a time under ideal laboratory conditions. For each ore, pre-concentrations were created and analyzed by third party for their respective mineral concentrations. The results of the test works and the potential impacts of the application of Automatic Sensor Based Sorting to each ore type are discussed.

9:45 am

Development of an in-Situ Floc Size Measurement System for Thickener Operation

Y. Yang, C. Braun, F. Schoenbrunn and G. Roy; FLSmidth, Midvale, UT

The addition of flocculant to the thickener feed slurry leads to particle agglomeration which increases the settling velocity. Flocculant overdosage is a very common problem in mineral processing plants due to the lack of online flocculation information. FLSmidth has developed an in-situ floc vision system to measure and monitor floc size, which will help plants to control flocculant usage and reduce operating cost. The agglomerate suspension behavior and thickener performance are determined by the floc size and structure. Although large flocs settle faster than small flocs, large flocs are not always desirable and can sometimes inhibit thickener's overall performance. The optimal floc size can be determined by checking the floc settling velocity and floc bed density. The floc vision system can be combined with FLSmidth's E-DUC® feed dilution technology and E-Volute™ feedwell. It has been tested in the laboratory as well as customers' full size thickeners. The system includes a submersible camera and corresponding software recording floc images and analyzing the floccule size in real-time. The floc size information can then be used by operators or DCS for reagent rate adjustment.

10:05 am

Use of Gravity Spiral Concentrators at Greens Creek Mill

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

Although Hecla's Greens Creek Mill primarily produces flotation concentrates, for many years it has also produced a gold-bearing gravity concentrate with grinding cyclone underflow used as gravity circuit feed and gravity spirals as roughers and cleaners. Until recently, gravity cleaner concentrate was reground in a rod mill before being recleaned on a shaking table. Table concentrate was processed onsite to produce doré bullion, with table middlings sent offsite for third-party processing. The regrind mill has now been eliminated, along with the shaking table, and a recleaner gravity spiral brought into use in their place. All gravity concentrate is now sent offsite. Other changes to the gravity circuit in recent years include increased numbers of spirals employed and decreased circuit feed volume. Operating characteristics and performance of gravity spirals for auxiliary precious metals recovery in a flotation mill will be discussed.

10:25 am

Technical and Economic Evaluation of Coal Middlings Processing

P. Bozzato[1], F. Peng[2] and N. Re[1]; [1]Ecomin, Genova, Italy and [2]Mining Engineering, West Virginia University, Morgantown, WV

Re-processing of middlings from dense medium separation is not new, but technical solutions and economic impact on plant design are now revisited due to modern mining practices, lower commodities prices, and advancing in modern multistage dense medium separation technology. Multistage dense medium separation technologies, such as the Tri-Flo® and the 3 Product Cyclone (3PC), are now accepted to produce two products, high quality product at low density separation, and low quality byproduct at high density cut. This work focuses on middlings re-processing to increase high value product yield as commonly done in mineral processing. Middlings can be recirculated to feed to recover misplaced material. Middlings washability can further be improved before recirculation including a crushing step. Main results and the methodology adopted in particle liberation studies is detailed to provide useful guidelines during the preliminary phases of a project. Examples of plant practices and their results are presented and discussed together with flowsheet simulations and economic evaluations.

10:45 am

Two-Mass Vibrating Screens for High Tonnage Applications

E. Wipf; EdRockMan IV LLC, Wonewoc, WI

As mine size and tonnage continues to increase, material handling/processing equipment has also increased in size. Related equipment including vibrating screens have also increased in size with screens seeing feed rates of 3000 MTPH. Open circuit SAG Pre-Crush and closed circuit HPGR flowsheets are becoming more common with large screening requirements. Large multi-slope (banana) or horizontal screens are commonly used for these applications, however as the size of these screens has increased, the number and size of the brute force/overhead exciters has increased but with limitations. An example is a SAG discharge screen that will see surges of material from the SAG mill which overload the screen, reducing the screen stroke or throw causing a large reduction in screen efficiency with excessive fines & moisture in the screen oversize feed to the pebble crushing circuit. This paper will present some actual examples of the use of Two-Mass screens as a solution to these overloading problems and the advantages of Two-Mass screens in other high tonnage applications.

11:05 am 17-068

Gravity Concentration of Chromite Fines

N. Duru; Mining and Metallurgical Engineering Department, University of Nevada, Reno, Reno, NV

Gravity concentration is still a challenging area in the mineral industry. This is mainly because of the fine size valuable mineral losses to the tailings during its application. But the recent developments in centrifugal separation methods and their mutual application with conventional separation techniques has increased mineral recoveries. In this paper, field application of conventional gravity separation methods with the combination of 2” diameter hydrocyclone cluster unit and a multi gravity separator (MGS) was discussed. Additionally, particle size distribution and chromite content of the plant streams is presented and initial laboratory test results were compared with the actual plant data throughout the paper. As expected, field data showed derivations from the laboratory tests but the combination of MGS and conventional gravity separation techniques resulted in gravity separation of -0.1 mm chromite particles.

11:25 am

CCD and High Density Thickeners – No-Brainer? a Doddle? Claro?

M. McCaslin; WesTech Engineering, Murray, UT

There are two key process functions in counter-current decantation (CCD): 1. Maximizing wash liquor contact with the incoming slurry and 2. Ensuring as much solution at the thickener overflow as practical. Because paste and high density thickeners are designed to produce high underflow solids, by

extension they maximize overflow liquid. Hence, they excel at item 2. While the use of such thickeners in CCD has been mentioned in other publications, the discussion was as a subset of larger paste/high density theses. This paper will focus solely on use of the technology in CCD, addressing the many advantages, but considering the disadvantages as well. Attendees will come away knowing that use of high density thickeners in CCD circuits is a straight-forward decision and how best to leverage that application.

TUESDAY, FEBRUARY 21

MORNING

9:00 am **Room 707**

MPD: Plant Design I: Plant Upgrades and Optimization

Sponsored by Moly-Cop USA, LLC

Chair: *D. Meadows, Bechtel, Phoenix, AZ*

9:00 am

Introduction

9:05 am

The cPlant at Al Amar Gold Mine

A. Priyambodo[2], L. Rudolphy[1] and B. Murphy[1]; [1]Flotation, Outotec, Denver, CO and [2]Maaden Gold, Riyadh, Saudi Arabia

The cPlant was designed as a modular flotation solution employing state-of-the art technology to minimize capital expenditure for small to medium flotation plants. The plant is based on a number of standard modules for both flotation equipment and ancillary operating equipment that are configured based on process requirements. The modules all fit inside standard sea containers and contain structural components so they can be easily transported to the most remote site. This not only reduces construction time onsite and the time taken to get the plant making concentrate but also cuts down on engineering requirements and associated costs. The first cPlant test modules were sold to Al Amar project in Saudi Arabia in January 2016. The Al Amar project is owned by Ma'aden Gold and is a 32 tph copper and zinc concentrator. The key stages of the process, from order placement to commissioning, will be highlighted as well as some of the lessons learnt along the way.

9:25 am **17-091**

Then vs. Now: an Update of OceanaGold's Haile Operation

C. Anderson, C. Larson, M. Deal, Q. Johnston and D. Carr; OceanaGold Haile Operation, Camden, SC

Construction of OceanaGold Haile Operation's mill near Kershaw, South Carolina is currently underway with first gold pour expected in late 2016. The mill is designed to treat 6,350 tonnes per day with minor upgrades required to achieve 8,270 tonnes per day. Optimization of numerous areas within the plant during detailed engineering, combined with a focus on de-risking the process, has resulted in numerous process changes since the initial design. This paper briefly describes some of the process changes that have been made, presents a commissioning strategy modelled after OceanaGold's Didipio successful commissioning, and identifies potential expansion opportunities.

9:45 am

New Ways of Using Operational Data to Create Value in Mining and Metallurgical Processing Sites

O. Bascur, C. Hertler and L. Garrigues; OSIsoft, LLC., Houston, TX

In recent years, metal producing companies have increased their investment in automation and technological innovation, embracing new opportunities to enable transformational change. Internet of Things (IoT) is one of many transformational initiatives, which can fundamentally revolutionize how industrial complexes operate. Applying the latest technologies has become a serious challenge to both management and technical teams due to their rapid change. This paper describes the use of real time analytics to capture time based event to analyze abnormal situations from the mining and mineral processing units. The use of self-services BI technologies with plant data. Creating value from data in cyclical environment is the key. Classifying data o in real time to transform the events in to opportunities is the key of creating value using operational intelligence tools. Examples show the way to leverage existing workers with information technology optimize the performance of their filter operations to extend their quest to reduce their energy and water consumption.

10:05 am

Thiosulphate Removal from Recycle Water at Greens Creek Mill

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

Thiosulphate ($S_2O_3^{2-}$) is spontaneously generated in water contacting pyrite and other sulphide minerals at a number of mines worldwide, including Hecla's Greens Creek Mine in Juneau, Alaska. When treated process water from the Greens Creek Mill is recycled for mine or mill uses, high rates of metallic corrosion occur in piping, valves, equipment etc., with dissolved thiosulphate suspected of playing a role. Thiosulphate removal from solution using nanofiltration has been investigated on a pilot scale and the use of ettringite precipitation is now being investigated. The effect of thiosulphate removal on corrosion rates will be discussed, as well as potential corrosion mechanisms.

10:25 am 17-024

Chromite Plant Capacity Increase Using Experimental and Modeling Techniques

Y. Vural[2], A. Acar[2] and e. tuzcu[1]; [1]Head of Mining and Mineral Processing, ANKARA, Turkey and [2]Mining Engineer, ANKARA, Turkey

In order to sustain the operations in chromite processing plants, due to concentrate selling cost, plants are in need of optimization in terms of capacity and recovery increase. In this study, DAMA Engineering carried out a methodological study for the purpose after a detailed sampling campaign in a plant which is situated in one the main chromite zones in Turkey; 1-The current status of the plant was investigated quantitatively with the bottlenecks, Plant overall efficiency in terms of recovery, Efficiencies of the particular equipment (mill, screen, gravity circuit), 2-A new circuit was proposed with the available equipment, 3-The new circuit that is product of modeling and experimental effort, was evaluated quantitatively as if it is a running plant, After 4-5 months continuous effort, the capacity of the plant was almost doubled (37 tph to 70 tph) and the plant overall recovery was increased from 48% to 63% by grinding adjustments and additional shaking tables theoretically. It was shown that the plant may move into profit with the minimum amount investment using readily available system.

10:45 am **17-005**
Adapting to a Cyclical Market - Intrepid Potash's Carlsbad, NM East Facility Transition
B. Berg, J. Mansanti and C. Nyikos; Intrepid Potash, Denver, CO

The Carlsbad East facility has produced muriate of potash (MOP) since 1965. In addition to MOP Intrepid Potash began recovering langbeinite from a mixed ore reserve in 2005. In 2011 a new langbeinite recovery process for the coarse (+850 micron) size fraction was constructed to enhance the overall langbeinite recovery. Based on the limited mixed ore reserve the transition of the East plant to a langbeinite only facility was targeted for 2021. Due to a decreasing grade of the mixed ore reserve, declining sales pricing, and high sylvite operating costs a strategic decision was made to accelerate the transition into 2016. To enable a successful transition, a fines recovery system needed to be developed constructed, and implemented. This paper describes the planning, development, and successful execution of the transition.

11:05 am
System Design Considerations for HPGR and SAG Circuits
C. Welsh[1] and D. Cantoni[2]; [1]OREqual Consulting, Swiftwater, PA and [2]GHD, Perth, WA, Australia

A comparison of SAG and HPGR plant circuit designs and requirements from the primary stockpile through to secondary ball mill feed at 10,000 tpd and 100,000 tpd level and their impact on operations and maintenance requirements. Analysis will include general process and maintenance equipment requirements, power, staffing, and plant layout considerations that should be evaluated before selection of which circuit to utilize for a new facility.

TUESDAY, FEBRUARY 21
MORNING

9:00 am **Room 106**
Underground Construction Association of SME: Tunnels and Shafts

Chairs: *J. Rostami, The Pennsylvania State University, University Park, PA*
J. Larsen, Sandy, UT

9:00 am
Instroduction

9:05 am

A Machine Learning Approach for Predicting the Performance of an Earth Pressure Balance Machine (EPBM) in Difficult Ground

S. Arora and R. Kaunda; Mining Engineering, Colorado School of Mines, Lakewood, CO

Although machine learning studies have been conducted for TBM performance in hard rock, relatively few have been done for EPBMs. A useful way of gauging performance is the use of the rate of advance (ROA), which comprises of penetration rate (PR), utilization factor, and other factors. An accurate estimation of ROA is fundamental to project planning and cost estimation. This study employs proper scientific procedures like machine learning algorithms for the prediction of one of the important inputs to ROA - the PR. The approach is illustrated by using example data collected from the University Link tunnel project in Seattle, WA. The dimension of the data is reduced by identifying the important EPBM's sensor data (representing different machine parameters: cutter head torque, rotational speed, etc.) that have a direct correlation with the PR. This reduced data set was then subjected to automatic feature selection (AFS), viz., principal component analysis and Gamma test to prepare two separate sets of input data to be fed to artificial neural networks (ANNs). The performance of ANNs was then analyzed in terms of their PR prediction capability to identify the best AFS technique.

9:25 am

TBM Excavation Technology for Mine Development and Production

D. Ofiara; Engineering, The Robbins Company, Solon, OH

Since the development of rock TBMs in the 1950s, several TBM type machines have been used to drive tunnels in mines. These machines include the typical circular cross section TBMs, and specialized machines that utilize disc cutters, but excavate non-circular cross sections. This paper reviews the success of these machines, and describes development and future application of this equipment in mining applications. The relative merits of various cross sections will be compared, and the excavation efficiencies of the machines that produce these cross sections. Continuous conveyor systems and other ancillary equipment is needed to allow efficient utilization of these excavation machines. These ancillary systems, and adaptations necessary for mining applications, will also be described.

9:45 am

Rehabilitating the Bingham Tunnel – Challenging the Means and Methods to Reduce Risk by Applying Technologies in Rehabilitation in a 60 Year Old Tunnel

M. Bartlett[1], m. haddock[2] and T. Adler[3]; [1]AusIMM, Sandy, UT; [2]Golder Associates Inc, St. Charles, MO and [3]Kiewit, Omaha, NE

The Bingham Tunnel is a historical rail haulage tunnel driven in the 1950's for access to the historical Lark mine. The tunnel is now used by the Rio Tinto's Bingham Canyon open pit mine located in Salt Lake City Utah for water management. The tunnel is situated on the east side of the open pit mine under the expanding East Waste Rock (EWR) mine waste dumps. Rehabilitation of Bingham Tunnel consisted of assessment and rehabilitation of 7500 linear feet in a 9 x 9ft tunnel. This case study highlights the challenges faced by the Bingham Tunnel Rehabilitation team relating to risk and execution in the Bingham tunnel and how this is tied to the risk management approach of all parties involved. The study also aims to highlight the innovative and new methodologies developed by the team to execute the work in a safe manner.

10:05 am

Development of Haulage Boring Machine

P. Rennkamp and S. Dube; Herrenknecht, Etobicoke, ON, Canada

The Haulage Boring Machine of Herrenknecht is a compact, mobile boring machine which achieves small diameters for access or production. Its compact layout is designed to enter the market and give an alternative to conventional methods which were the only option when Tunnel Boring Machines could not achieve the diameter requirements. This paper will outline the functionality as well as new development stages including material handling, detailed engineering and rock strength capabilities.

10:25 am

Improved Roller Cutters for Shaft Excavation

D. Krauter and S. Dube; Herrenknecht, Etobicoke, ON, Canada

One type of roller cutting excavation tools that are often used on a variety of mechanical underground excavation machines are Multi-row tungsten carbide insert (TCI) roller cutters. Herrenknecht has recently implemented several improvements in the design of multi-row TCI cutters to increase load capacity, reduce body washout and improve high pressure sealing applications. This paper will detail these improvements and present projects where these cutters have been successfully used in challenging shaft boring applications.

10:45 am

Development and Evaluation of the Inflatable PythonM3 Bolt and Innovative PyFlexU2™ Coating against Highly-Corrosive Ground Conditions

K. Ma, J. Stankus, D. Faulkner and L. Ma; Keystone Mining Services LLC, Jennmar Corp, Pittsburgh, PA

Inflatable rock bolts are widely used in hard rock mines as an efficient ground control product. However, its capacity and service life can be significantly reduced if the metallic body is subjected to corrosion. In some hard rock mines in the U.S., highly corrosive ground condition exists, and has been reported that inflatable rock bolts corroded within a few months of installation. The unexpected failure and short service life resulted in roof falls, interrupted mining operations, and consequently required constant rehabilitation. In the past, the mining industry commonly relied on either a cathodic sacrificial coating (galvanization, zinc epoxy, etc.) or barrier type coating (epoxy, polyurethane, plastic, etc.) to protect the roof bolt. However, in highly corrosive conditions, the coating systems are either ineffective or vulnerable due to coating micro-cracking and/or splitting during inflation, and scratch damage by borehole sharp edges during bolt insertion, all of which exposes the metal to the corrosive medium.

11:05 am

Application of Ground Support Spiling in a Vertical Shaft – Nevada Copper Pumpkin Hollow East Shaft

M. Miniely; Mining Operations, Cementation USA, Bunker, MO

Nevada Copper's Pumpkin Hollow Property is a high-grade skarn/Iron Oxide Copper Gold (IOCG) deposit located within a porphyry copper district in Lyon County, Nevada, USA. Construction to support accessing the underground operation began in 2012, with the 1900 level reached in 2015. The East Shaft was constructed by blind sinking method, with the upper portion of the shaft having good to fair ground conditions. A zone encountered below mid shaft, approximately 1,000 feet below surface, required additional support over and above the prescribed temporary support consisting of friction bolts, screen, and shotcrete, prior to installing the permanent lining. Cementation Operations, Engineering, and Project Services groups, along with client representatives, developed a method that consisted of installing spilings vertically, in order to support the rock prior to excavation, allowing safe access to install the prescribed temporary support. This presentation will discuss the challenges and successes that went along with the application of the pre-supporting system.

11:25 am

An Optimum Design for Hard Rock TBM Site Installation

O. Frough and J. Rostami; Dept. of Energy & Mineral Engineering, Pennsylvania State University, State College, PA

One of the most important items in mechanized tunneling is TBM Launching portal design for TBM assembly, commissioning of tunnel boring and supplying the tunnel operation. The minimum required length and width of the portal is depend on length of TBM and back up, transport system type, muck discharging capacity, storage areas and workshops. An optimum length and well arrangement site design is more productive than a large uncoordinated tunnel site. The portal activity has a greet roll in TBM downtimes and utilization factor. In order to design a site installation the location of access roads, topography, excising rivers and other facilities must be considered. In this presentation the basic principle of the site installation design for hard rock TBM tunneling will be discussed and some case studies in different situation will be explained.

TUESDAY, FEBRUARY 21

AFTERNOON

2:00 pm **Room 107**

Bulk Material Handling: Improvements in Conveyor Reliability and Availablility

Sponsored by Siemens

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

2:00 pm

Introduction

2:05 pm **17-072**

Improving Conveyor Transfer Point Performance in Hard Rock Mines

R. Shields and A. Marti; Corporate Marketing, Martin Engineering, Neponset, IL

Hard rock mines move large volumes of material. But the conveyors essential to this movement suffer lots of problems, including carryback, spillage, dust, and belt wander. Many of these issues are created at the transfer points where the belts are loaded. This presentation will start with an overview of the latest transfer point systems that incorporate safety and serviceability by design. He will then report on recent projects. One project is the Conveyor B Transfer at the Coeur Rochester silver mine near Lovelock, Nevada. Here performance was improved with the installation of belt support cradles, engineered chute walls with external wear liner, and a compact dust collector. A second project is the improvement of belt support idlers and skirtboard sealing in the loading zone on Conveyor Number 9 at Freeport-McMoran's Morenci Mine in Morenci, Arizona. The objectives of this presentation include allowing mine personnel to understand the technologies available to improve transfer points. The presentation will provide a frame of reference to examine an operation's conveyors, to consider what improvements could and should be made, and the benefits these improvements would provide.

2:25 pm
Improve Bearing Service Life and Your Operations Using Sealed Bearings on Conveyors
J. Goldman[1], R. Baratta[2] and J. Oliver[3]; [1]Applications Engineering, SKF USA, Lansdale, PA; [2]Mining Industry Specalists, SKF USA, Lansdale, PA and [3]Director of Industry Specialists, SKF USA, Lansdale, PA

Conveyors are integral to mining operations as they feed operations throughout the entire process. When a primary conveyor goes down, costly repairs and a loss of valuable production time are incurred. Frequently, the interruption in conveyor operations is caused by a premature bearing failure on a pulley. Changing a pulley bearing can be a dangerous, lengthy, and labor-intensive activity. Sealed bearings coupled with a proactive and predictive maintenance program have been shown to virtually eliminate premature bearing failures and, at the same time, dramatically reduce grease consumption; consequently, reducing the need for maintenance, which improves worker safety and allows them to focus their time on other duties. This paper will explore the causes of these bearing failures and how to implement the solution accompanied by case studies where adopters have significantly reduced unplanned downtime, extended bearing service life, reduced maintenance expenditures and ultimately improved their bottom line.

2:45 pm
Evaluating Transfer Chute Design for Increased Throughput or for Use with a Different Material
C. Hartford; Jenike & Johanson, San Luis Obispo, CA

In this cyclic environment, capital costs are kept to a minimum during downturns. This requires existing assets to be used to their full potential. Other times it means exploring different types of material to mine while using the existing equipment to handle the different ore. While these changes may make sense on the books, it critical to evaluate how the new material or increased throughput will flow in the existing system. When a plant increases throughput or changes the material, handling equipment such as belt-to-belt transfer chutes often fail to perform reliably. Some of the problems associated with failed chute designs include: plugging, excessive wear of chute surfaces, unacceptable dust generation, high belt wear, and product spillage. These problems often lead to significant maintenance costs because of the need to unplug chutes, pick up spillage, or frequently replace wear liners. Poorly performing chutes can cause environmental problems and production losses. This talk discusses the best approach to evaluate if the throughput of an existing transfer chute can successfully be increased, and whether or not a new material will flow through an existing chute.

3:05 pm

Methods to Increase the Availability of Mine Hoisting Systems

R. Gebhard; PD SLN MN / Minerals, Siemens AG (Germany), Erlangen, Germany

Not every "peanut" leads to a breakdown. How to realize this requirement? The presentation describes different methods to increase the availability of mine hoists. A common way of realisation is to install redundant systems. As a second method the minimisation of shut-downs and the reduction of shut-down-time need to be considered. We will show and explain different solutions on the example of installed systems. The importance of availability sometime depends on the type of the hoist. At production (or rock) hoists the amount of hoisted material is the key figure. At service (or personnel) hoists mainly the safety of personnel needs to be considered, not to forget the availability to transport people under every circumstance. Sometimes it seem that words like "safety", "availability" or "price" don't match. We will show that you can combine this aims. Newer concepts for low voltage solutions show how to increase availability without spending the double amount of money for a redundant system. We are going to show concepts and solutions realised in different countries. For example in Asia, Europe or South Africa.

TUESDAY, FEBRUARY 21

AFTERNOON

2:00 pm **Room 704**

Coal & Energy: Blasting and Explosive Technologies for Surface Coal Mines

Chairs: *J. Silva, University of Kentucky, Lexington, KY*
E. Jong, Virginia Tech, Arlington, VA

2:00 pm

Introduction

2:05 pm

Comprehensive Shock Physics Studies of Air-Deck Behavior During Rock Blasting

D. Preece[1], D. Johnson[2] and R. Yang[3]; [1]Technology, Analytics & Automation, Orica Mining Services, Saratoga Springs, UT; [2]Explosives & Initiating Systems, Orica Mining Services, Watkins, CO and [3]Blast Modeling Development and Support, Orica Mining Services, Watkins, CO

Air-decks are often employed in rock blasting for presplitting along the final highwall of a blast and are sometimes also included elsewhere in explosive columns. Shock wave physics is an important part of air-deck behavior since the bulk explosives in the column impart a shock into the air-deck where the air shock then passes through the air-deck at a velocity substantially less than the explosive VOD. Air-shocks ring back and forth in the air-deck for a few 10's of milliseconds. When the shock wave reflects off the sides and bottom of the blasthole, the pressure is doubled for a few milliseconds. The magnitude of this reflected pressure is at least an order of magnitude less than the detonation pressure. Replacing high energy explosives with zero energy air-decks in a blasthole will always have a negative impact on the adjacent rock fragmentation and movement. The behavior of air-decks in explosive columns is well understood and can be modeled with shock physics theory as well as with finite difference or Lagrangian computer programs. Both approaches will be used in this paper to aid those interested in understanding the behavior and impact of air-decks in blasting.

2:25 pm

Prediction of Rock Fragmentation in Bench Blasting Using Neural Networks

P. Sinha; Mining Engineering, Indian School Of Mines, Dhanbad, Dhanbad, India

Despite of technological advancement in the field of rock breakage, blasting is still an economical means of rock excavation for mining and civil engineering projects. Considering the various blast parameters together to predict the fragmentation is subtle and can lead to wrong conclusions. In this paper, a different approach has been followed to combine the representational power of multilayer neural networks and various machine learning techniques to predict the fragmentation of a bench blast using the data from a limestone ore mine located in central India. The results obtained here, are compared with those predicted by image analysis method and it has been observed that neural networks can be used efficiently in such cases with a high degree of accuracy. The sensitivity analysis has been done to get the relative importance of the variables in prediction of the output. The results obtained in this study and the methodology introduced, can assist the mining design engineer to decide on a drilling and blasting pattern that produces the most suitable fragmentation of the blasted ore and hence minimize the total cost of the mining operations.

2:45 pm 17-096

Precision Presplit Design

A. Konya and C. Konya; Explosive Engineering, Precision Blasting Services, Montville, OH

In the mining industry highwall stability is often a major concern for both the safety of the employees and the overall feasibility of the mine. Traditionally, mines employee some form of overbreak control in their blasting process to help protect the final walls and allow for steeper pit slope angles. This overbreak control is typically in the form of: airdecking, buffered blasting, cushion blasting, or traditional presplitting and works with varied results. Typically these methods suffer in weaker or highly structured rocks leading to insufficient results in the form of backbreak or large toes; forcing the mine to employee secondary blasting or modify mine plans. In this paper the authors have created and tested a new method of presplitting termed "Precision Presplitting" which is now being used worldwide in major mines and large construction project. This method of presplitting uses both the rock mechanics and structural geology to design a highly-controlled, reliable final wall while mitigating backbreak and toe problems. The authors have also developed models to determine the presplit factor of rock and design an appropriate presplit for any rock type at variable spacing.

3:05 pm 17-061
Evaluation of Blasting-Induced Ground Vibrations on Highwall Stability
R. Eades and K. Perry; Mining Engineering, University of Kentucky, Paris, KY

Highwall miners continue to be implemented by operations to increase recovery, improve margins, and justify higher stripping ratios as high quality surface reserves become increasingly rare. Many times, operations facilitate projected underground operations by leaving an intact highwall for development purposes. These facts result in larger highwalls that are left standing for increased periods of time prior to reclamation. As a consequence, worker exposure and risk is also been elevated, resulting in higher potential for accidents or fatalities relating to surface highwalls. Highwall stability is a complex issue, dependent on both geologic and mining factors. Dynamic numerical modeling offers the capability to assess possible stability issues related to blasting-induced ground vibrations. Research has been conducted to evaluate the effect of highwall stability due to ground vibrations from blasting events. Additionally, the relationship of amplitude and frequency, and their impact on highwall stability is investigated. The results of this modeling indicate that amplitude has little impact on stability. However, frequency has a significant impact on highwall stability.

3:25 pm
Approach to Predict Ground Vibrations in Surface Blasting Using Artificial Neural Network
K. BHATIA; Mining Engineering, Indian School Of Mines, Dhanbad, Dhanbad, India

In surface blasting, ground vibrations is one of the principal disturbances caused. The explosion energy, which breaks the rock mass, is not fully utilized and gets wasted in the form of ground vibrations, air blast, fly rock, etc. Among them, ground vibrations is considered to have most damaging effect. In this paper, attempts have been made to investigate the potential of ANN in prediction of ground vibration due to blasting in open pit mines. The PPV and Scaled Distance are taken into consideration to develop an empirical formula. However, these relationships are not able to consider the variation in rock parameters and uncertainty of Insitu conditions. The formula generated will be compared with the available empirical formulas for blast vibrations predictions. Key words: ground vibrations, PPV, Scaled distance, ANN.

3:45 pm
Deconvolution of Blast-induced Ground Vibration by Wiener Filtering
L. Li and J. Silva; Department of Mining Engineering, University of Kentucky, Lexington, KY

Ground vibration is one of the environmental concerns caused by mine blasts. The signature hole technique, essentially the convolution of a single-hole vibration waveform (also called a signature waveform) with a timing sequence, is one method used to predict and control ground vibrations. This method first requires measuring a signature waveform, which may be a limitation. Deconvolution of vibration signals from a production blast can solve that limitation. Among the diverse approaches to deconvolution, the Wiener filtering is one of the most widely used methods. The timing sequence is assumed as known in electronic detonation. Then a Wiener filter can be designed to compress a blast signal into spikes in accordance with the timing sequence. The resultant Wiener filter is actually the inverse of the signature waveform. The proposed methodology in this paper will eliminate the need for measuring signature waveforms by using all the seismograph information collected in regular mine operations. The methodology can also be combined with the improved signature hole technique proposed by Silva (2012) for ground vibration reduction.

TUESDAY, FEBRUARY 21
AFTERNOON

2:00 pm **Room 711**
Coal & Energy: Dust Control I

Chairs: *T. Beck, NIOSH, Pittsburgh, PA*
P. Conrad, Montana Tech, Butte, MT

2:00 pm
Introduction

2:05 pm
Considerations for the Construction of a Face Ventilation Gallery in an Underground Limestone Mine Using Computational Fluid Dynamics Modeling
B. Coleman, W. Wedding and T. petrov; Mining Engineering, University of Kentucky, Lexington, KY

The Department of labor has recently enacted decreased respirable dust exposure limits in coal mines along with laws which require continuous monitoring and immediate correction when exposed to dangerous levels. Engineering controls in the coal mining face must improve to protect the health and safety of miners. A full scale test gallery is being constructed to investigate the effectiveness of current methods and help develop new solutions to the problem of face ventilation. Our design of a full scale coal mine face includes an intersection with a face extending 15 meters (50 feet) forward. On the right and outby sides, we have a 6 meter (20 feet) entry and on the left we have a 2.4 meter (8 feet) section to serve as the exhaust. The gallery will be 2.1 meter (7 feet) tall and will include a mockup of a continuous miner with a functional scrubber and body sprays. The gallery will also be located in an underground limestone mine, which can provide its own set of problems. This research project investigates the possibility of recirculation of air through the gallery given the conditions at the location through the use of computational fluid dynamics modeling.

2:25 pm
Numerical Modeling of Particle/Droplet Interaction to Evaluate Dust Control in Mining
J. Swanson[2] and C. Negoita[1]; [1]Oregon Institute of Technology, Klamath Falls, OR and [2]Staffordshire University, Stoke-on-Trent, UK

Spray systems are a common method used for dust control in mining, often provided by a manufacturer or chosen based upon experience. This does not always lead to the best dust control. An understanding of relative sizes of water droplets and dust particles as well as relative speed, concentration and properties combined with the interaction environment provides the information needed to evaluate the quality of a dust control system. A mathematical model that uses these criteria allows the miner to evaluate the best nozzle to install. Using Navier-Stokes Equations, the flow around a water droplet is modeled and modified to represent the two-phase fluid flow. The dynamics of the system are governed by the continuous phase of ventilation air containing dust particles and the relative velocity to the water droplets. Incorporating the momentum equations, the pathlines of the dust particles and collision with water droplets can be described. The capture efficiency of a nozzle can be taken from the model. Providing the engineer with simple nozzle selection criteria based upon known information will provide for a better use of water and best dust control for specific applications.

2:45 pm 17-026

Comparison of Different Hollow Cone Water Sprays for Continuous Miner Dust Control Applications

S. Klima, C. Seaman, J. Organiscak and S. Mischler; NIOSH, Jefferson Hills, PA

Researchers at NIOSH's Pittsburgh Mining Research Division performed comparative testing of six hollow cone water sprays; static sprays from Spraying Systems (BD-3, BD-5) and Steinen-Hahn (SH-3, SH-5), and self-cleaning sprays from Repair King (RK-3, RK-5). Water flow testing was completed at 60, 80 and 100 psig for both sets of sprays (3s and 5s). Airflow induction testing was completed at 80 psig using a hot wire anemometer to take air velocity measurements upstream of the sprays. Respirable dust capture efficiency testing was completed in a 512 ft^3 closed system dust chamber at 80 psig. Sprays were analyzed with a Cloud Aerosol Spectrometer, using light scattering to count and size the airborne water droplets from each spray. Water flow testing produced deviations less than 8% from the average water flow rate for each set of sprays. The RK-5 spray showed the largest difference in airflow induction, moving just over 76% of air compared to the BD-5 and SH-5 sprays. The dust capture efficiency for the 3 series sprays ranged from 7.2% to 9.9%, while the 5 series sprays ranged from 5.3% to 7.1%. Spraying Systems sprays produced the largest mean droplet size of the three manufacturers.

3:05 pm

Computational Fluid Dynamics (CFD) Modeling of Dynamics of Liquid Film Circulating Inside a Reduced Scaled Model of a Vortecone Scrubber

A. Kumar, W. Wedding and S. Arya; Department of Mining Engineering, University of Kentucky, Lexington, KY

Dust is a nuisance in all underground mining operations. Scrubbers are commonly used in underground room and pillar coal mines to reduce miners' exposure to respirable dust. Particulate exposure in the working environment occurs in other industries, such as automotive painting. This research effort is a technology transfer of a scrubber developed for controlling automotive overspray, named the Vortecone scrubber. The Vortecone works on the principle of centrifuges. Dust laden air and water are drawn into the device. Dust particles are preferentially carried towards the outer curved surface of the mixing chamber. This curved surface is continually wetted by a supply of water providing a means to capture the airborne dust. The spent water is then brought out of the system via the outlet thereby cleansing the air of dust. Varying the quantity of water is expected to affect the performance of scrubber. The paper discusses the modeling of dynamics of a thin film in a one-third scaled vortecone system. CFD models show the phases of thin film running on the internal surfaces of the scrubber and air under the combined effects of centrifugal forces, gravity and surface tension.

3:25 pm 17-082
Material Property Tests of Foam Agents to Determine Their Potential for Longwall Mining Dust Control Research

W. Reed, T. Beck, Y. Zheng, S. Klima and J. Driscoll; DCVTSB, NIOSH, Pittsburgh, PA

Foam has been used for past dust control in mining and is currently being reconsidered for use in underground coal longwall operations to help comply with MSHA's lower coal mine respirable dust standard (1.5 mg/m3). Foams were generated using two different methods. One method made compressed-air-generated (CA) foam, while the other method used a NIOSH developed foam generator which produced blower-air-generated (BA) foam. Three foam property tests were used to classify foams; bottle shake test, foam expansion ratio, and water drainage. The bottle shake tests determined that the lowest concentration of foam agent to be used was about 1.5%. CA foams tended to have low expansion ratios (10-19) with high water drainage. BA foams had higher foam expansion ratios (30-60) with lower water drainage. Foams produced within these ranges of expansion ratios are stable and potentially suitable for dust control. Results of testing eliminated two foam agents for future testing due to poor expansion ratios. These material property tests can be used to classify foams for their research potential in longwall mining dust control.

3:45 pm 17-077
Investigation on the Use of Chemical Dust Suppressants on Ash Emissions due to Fort McMurray Wildfire

D. Omane, H. Yu, W. Liu and Y. Pourrahimian; School of Mining and Petroleum Engineering, University of Alberta, Edmonton, AB, Canada

A large scale wildfire had broken out at Fort McMurray in Alberta, Canada during May 2016. Many oil sands mining activities were affected due to the wildfire and its ash emissions. Ash emission generated from fire outbreak is also a huge problem during post-fire clean up. These emissions pose a health hazard to workers, create environmental problems and enhance global warming. This emission is caused either by human activities or wind effect. The objective of this research is to monitor the effect of dust suppressants (#1 surfactants and #2 polymers) at various dilutions on ashes from Fort McMurray. It is found that both #1and #2 suppressants are highly effective in retaining Fort McMurray dust at different dilutions. All dilutions tested (0.05% for #1 and 5% to 15% for #2) provide dust retention rate greater than 99% five minutes after suppressant spraying. It is found that both suppressants maintain a dust retention rate higher than 99.6% after 24 hours while water's retention rate drops to 97.6%, suggesting that dust suppressants has merit over longer period of time, which is proven by the 72 hour data.

4:05 pm
Comparison of Respirable Mine Dust Characteristics Across Mines in Central and Northern Appalachia

V. Johann, C. Keles and E. Sarver; Mining and Minerals Engineering, Virginia Tech, Blacksburg, VA

Increased incidence of coal workers' pneumoconiosis (CWP) and related occupational lung diseases amongst underground coal miners in parts of Appalachia has prompted research on the issue. One focus has been on specific mine dust characteristics that may provide insights into health outcomes. Over 16 months, 210 samples of respirable dust were collected in eight underground coal mines, including two in Northern Appalachia, four in Central Appalachia, and two in South Central Appalachia. These oper-

ations vary in terms of mining method, coal seam thickness, and mined strata geology. Dust samples were taken in various locations within each mine, including in the intake and return, near the feeder or conveyance, and near major production activities such as coal cutting and roof-bolting. An automated SEM-EDX routine was implemented to characterize up to 500 respirable dust particles per sample such that distributions in size, shape, and chemical composition could be determined. This paper compares results between and within mines, and also examines relationships between dust particle size, shape, and chemical composition.

TUESDAY, FEBRUARY 21

AFTERNOON

2:00 pm **Room 706**

Coal & Energy: Rare Earth Mineral Extraction from Coal Tailings & Byproducts

Chairs: *M. Fan, Eriez Manufacturing Co., Erie, PA*
A. Noble, West Virginia University, Morgantown, WV

2:00 pm
Introduction

2:05 pm **17-129**
Process Evaluation and Flowsheet Development for the Recovery of Rare Earth Elements from Coal and Associated Waste

R. Honaker[1], J. Groppo[1], R. Yoon[2], G. Luttrell[2], A. Noble[3] and J. Herbst[3]; [1]Mining Engineering, University of Kentucky, Lexington, KY; [2]Mining and Minerals Engineering, Virginia Tech, Blacksburg, VA and [3]Mining Engineering, West Virginia University, Morgantown, WV

Recent studies have revealed that the coal and coal byproducts produced annually contain enough rare earth elements (REEs) to meet current U.S. demand. The REEs exist in the form of minerals, ion-exchanged elements associated with clays and chemically bonded elements within the organic coal matrix. Researchers at three universities have collaborated to evaluate the effectiveness of existing physical and chemical concentration processes for the recovery of the REEs. The efforts have found that physical separation processes have the ability to increase the total REE content in the thickener underflow material collected from a Central Appalachian coal cleaning facility from around 300 ppm to values greater than 9500 ppm on an ash basis. On the other hand, leaching was effective in recovering REEs from coarse middlings materials collected from multiple coal basins as indicated by recovery values exceeding 85%. Based on material characterization data and process evaluations conducted for a number of potential feed coal sources, economic recovery of the REEs will require byproduct production of both clean coal and REE concentrate using a process flowsheet that is unique for each source.

2:25 pm

Assessing the Potential of Acid Mine Drainage Sludge as Rare Earth Elements Feedstock

P. Ziemkiewicz; Water Research Institute, West Virginia University, Morgantown, WV

During this study we found that metal precipitates resulting from acid mine drainage treatment (AMD sludge) contained, on an average 500 mg total rare earth elements (TREE)/kg on a dry weight basis. TREE ranged from 1,435 mg/kg (g/t) to a low of 0.6 mg/kg. Most of the samples (73%) exceeded 300 mg TREE/kg and 50% exceeded 427 mg TREE/kg. The lowest TREE values resulted from treatment of circumneutral AMD and the highest values from AMD with pH < 4.5. Even higher average concentrations (1,137 mg TREE/kg) resulted from AMD treatment plants using caustic soda cf. hydrated lime as the neutralizing agent. Laboratory experiments indicated nearly 100% extraction of REE from AMD precipitates under acid leaching and re-precipitation as pH was adjusted upward. This confirmed that these REE are present in AMD precipitates as hydroxides/oxy-hydroxides and their dissolution/precipitation response is nearly identical to that of Fe^{3+}. Preliminary findings indicated that the ratio of critical to non-critical REE was found to exceed a ratio of 1.0 across 30 samples.

2:45 pm

Plasma-Based Rare Earth Element Recovery from Coal Fly Ash

K. Jeffers and J. Renew; Southern Research, Birmingham, AL

Southern Research is evaluating the feasibility of an innovative process for concentrating rare earth elements (REEs) from coal fly ash (CFA). The process uses plasma technology in 2 proposed steps. Step 1 is a smelting process to separate coal ash into slag and metal layers where it is expected that the REEs will collect into the metal layer. In Step 2, the molten metal pool is volatilized, and the vapors are condensed in sequential temperature zones to produce REE-enriched metal fractions. The initial project work includes acquiring coal ash samples from several coal-fired power plants fueled on eastern bituminous coal and characterizing the ash for REE content. A comprehensive feasibility study will be conducted including bench-scale experiments using a plasma furnace to determine the fate of REEs in the separation between the slag and metal layers, evaluation of potential enhancements to promote the partitioning of REEs to the molten metal layer, and the plasma volatilization of the molten metal layer will be modeled, including the sequential condensation of REE-enriched vapors.

3:05 pm 17-103

Recovery of Valuable Elements from Chinese Coal and its by-Products

M. Fan[1], Y. Zhao[2], Z. Long[3] and W. Liu[4]; [1]Eriez Flotation Division, Eriez Manufacturing Co., Erie, PA; [2]School of Chemical Engineering and Technology, China University of Mining and Technology, Xuzhou, Jiangsu, China; [3]Guizhou Shuicheng mining (Group) Co., Ltd, Liupanshui, Guizhou, China and [4]Datong Coal Mine Group Co., Ltd, Datong, Shanxi, China

This paper presents the concentrations of valuable elements including rare earth elements in various Chinese coal deposits and their corresponding coal by-products. Some economic potential recovery methods are discussed in this study. Magnetically stabilized air-dense medium fluidized bed separation, tribo-electrostatic separation, and froth flotation technologies are evaluated in recovering various valuable elements in Chinese coal and coal by-products from different coalfields. These valuable elements include rare earth elements, gallium, lithium, phosphorus, and germanium, etc.

3:25 pm 17-083

Maximizing REE Enrichment of Alaskan Coals Using Froth Flotation

T. Gupta, T. Ghosh, G. Akdogan and S. Bandopadhyay; Mining Engineering, University of Alaska Fairbanks, Fairbanks, AK

Rare Earth Elements (REEs) and their compounds are in high demand due to their numerous commercial and critical applications. Cost effective and eco-friendly opportunities are being explored for extraction of REEs from non-conventional mineral sources such as coal and coal by-products to stabilize the supply chain. Coal from Central Alaska (Healy Coal Mine) and Southern Alaska-Cook Inlet (Wishbone Hill) provinces have been found to possess elevated concentrations of critical REEs. The objective of the study was to enrich the REEs in the fine size fraction (-75 Microns) from Healy and Wishbone Hill by Froth Flotation. A Box-Behnken design was applied for modeling and optimizing the operating variables such as frother dosage, pulp density and collector dosage of Froth Flotation to maximize REE enrichment. The optimum flot conditions for maximum REE enrichment in the froth fraction were at 4.2% Solids and 32.7 ppm of Frother dosage for Healy Coal sample and 10% Solids and 37.9 ppm of Frother dosage for Wishbone Hill Coal sample. The empirical relationship for modelling and optimizing the response variable were found to be independent of Collector Dosage.

3:45 pm

Application of Hydrophobic-Hydrophilic Separation (HHS) Process for the Recovery of Rare Earth Minerals from Coal Refuse

B. Li, S. Park, N. Gupta, G. Luttrell and R. Yoon; Mining & Minerals Engineering, Virginia Tech, Blacksburg, VA

Rare earth elements (REEs) are critically important in advanced manufacturing, renewable energy and defense industries. Significant amounts of REEs are present in coal that can potentially be recovered as byproducts using physical and chemical separation methods. A challenge associated with physical separation is that the rare earth minerals (REMs) are of micron and submicron sizes. Therefore, it is difficult to recover them by flotation, which is inefficient with ultrafine fine particles. In the present work, REM concentrates have been recovered from fine coal refuse streams using the hydrophobic-hydrophilic separation (HHS) process. Initially, the HHS process is used to produce low-ash and low-moisture clean coal products and subsequently salable REMs concentrates. In the latter step, potassium octyl hydroxamate (KOHX) has been used to selectively hydrophobize REMs. SEM images of the concentrates show a large number of liberated REMs, while those of the tailings show some REM particles interlocked with gangue. It appears that the HHS process is very efficient with the recovery of ultrafine particles, the fundamental reasons for which will be discussed in this presentation.

4:05 pm 17-128

Chemical Extraction of Rare Earth Elements from Coal Ash

M. Peiravi[1], L. Ackah[1], R. Guru[1], M. Mohanty[1], J. Liu[1], X. Bing[2], Z. Xiaobo[2] and L. Chen[2]; [1]Southern Illinois University Carbondale, Carbondale, IL and [2]College of Chemistry and Chemical Engineering, Henan Polytechnic University, Henan, China

The overall goal of this laboratory-scale study was to develop a suitable flow sheet to extract rare earth elements (REEs) from coal ash. An anthracite coal sample, originating from the Lykens Valley #2 seam in Pennsylvania, was

found to have the highest REE concentration of more than 700 ppm (in the coal ash) among a total of fourteen coal samples of different ranks examined. The same sample was used for the REE extraction tests, that included high temperature leaching using nitric acid, followed by the solvent extraction tests. A 4x2x2 experimental design was used to conduct a total of thirty-two high temperature leaching experiments by varying acid molarity, solid content and leaching time. The highest LREE (light REE) recovery of 90% and HREE (heavy REE) recovery of 94% were obtained from the most optimum leaching test condition while maintaining the impurity recovery the leachate at less than 40%. Solvent extraction experiments were conducted to extract the REE's from the above leachate solutions using extractants such as, TBP, Cyanex, D2EHPA and their combinations. D2EHPA was found to be the best extractant during this SX text series providing nearly 99% recovery of REEs.

TUESDAY, FEBRUARY 21

AFTERNOON

2:00 pm **Room 702**

Coal & Energy: Refuge Alternatives for Underground Coal Mines II

Chairs: *D. Yantek, NIOSH OMSHR, Pittsburgh, PA*
T. Lutz, DHHS/CDC/NIOSH, Pittsburgh, PA

2:00 pm
Introduction

2:05 pm **17-104**
Refuge Alternatives Relief Valve Testing and Design with Updated Test Stand

T. Lutz, P. Bissert, G. Homce and J. Yonkey; PMRD, DHHS/CDC/NIOSH, Pittsburgh, PA

Underground refuge alternatives (RAs) require an air source, This requires pressure relief valves (PRVs) to prevent unsafe pressures. Research to date by NIOSH suggests that the design and implementation of RA relief valves has not yet had sufficient performance analysis or technical development. In response to this need, NIOSH tested a variety of PRVs using an instrumented test fixture with computer data acquisition using a centrifugal blower, ductwork, and various sensors to determine if they meet the MSHA requirement. Relief pressures and flow characteristics including opening pressure, pressure drop and flow rate were measured for 5 PRVs. Testing included two modified check valves, two check valves used in MSHA approved built-in-place (BIP) chambers, and a commercially available valve that was designed for a steel RA and used in some BIP RAs. The test results showed relief pressures ranging from 0.6 kPa to 1.5 kPa and flow rates from 10.1 to 18.0 m3/min. All of the relief valves met the MSHA maximum relief pressure specification except the commercially available valve designed for a steel RA.

2:25 pm

Design and Construction Considerations for Compressed Air Lines to Refuge Alternatives

R. Lamont and J. Silva; Mining Engineering, University of Kentucky, Lexington, KY

Entrapment of underground mine workers may result from mine disasters such as explosions, fires, and major collapses. The 2006 MINER Act recognized this danger to the health and safety of underground coal miners, and established requirements regarding emergency breathable air supplies for each worker at underground “Refuge Alternatives”. Industry compliance with these supply levels has thus far centered on discrete volumes stored in tanks. A preferable solution would provide an unlimited air supply by installing a transport system (compressed airlines) from surface site(s) to refuge locations throughout the mine. Air supply system design must be capable of withstanding normal mine operational hazards and possible disaster events, while emphasizing ease of installation and economic viability. A NIOSH funded project was awarded to the University of Kentucky to carry out research regarding the design and construction of possible air supply systems. This presentation covers testing of various airline materials and protection methods. The conclusions obtained through analysis of the results will be presented and used to offer a set of recommendations and design considerations.

2:45 pm 17-098

Prediction of Human Core Temperature Rise and Moisture Loss in Coal Mine Refuge Alternatives

M. Klein[1], D. Yantek[2], M. Hepokoski[1] and L. Yan[2]; [1]ThermoAnalytics, Inc., Calumet, MI and [2]CDC NIOSH, Pittsburgh, PA

NIOSH research has shown that heat/humidity buildup is a major concern with refuge alternatives (RA). These high temperature and humidity levels inside a RA may expose occupants to heat stress. Due to the safety risks associated with testing using human subjects, NIOSH partnered with ThermoAnalytics to create detailed thermal simulation models of shelters with human occupants. The objective of this effort was to predict a miner’s core temperature response and moisture loss in environments that may be encountered in a coal mine RA. These parameters were studied across a range of temperatures and relative humidity values to determine if the current 95°F apparent temperature limit for RAs is reasonable. The results indicated that the 95°F apparent temperature limit is protective provided that miners are supplied with sufficient water. The results also indicated that the body core temperature did not reach dangerous levels even at an apparent temperature of 130°F. However, the results showed that moisture loss increases with apparent temperature. Therefore, if the apparent temperature limit were increased, the water provided in an RA would have to be increased to offset moisture loss.

3:05 pm 17-069

Heat/Humidity Tests of a Built-in-Place Refuge Alternative

D. Yantek, G. Homce, L. Yan, T. Lutz, J. Srednicki, J. Yonkey and R. Matetic; NIOSH PMRD, Pittsburgh, PA

Federal regulations require the installation of refuge alternatives (RAs) in underground coal mines. Of the in-use RAs, over 95% are mobile RAs with the remainder being built-in-place (BIP) RAs. Heat/humidity buildup has been one of the major concerns with mobile RAs. For BIP RAs, however, there is a lack of in-mine heat/humidity test data to determine the extent of heat and humidity buildup. To quantify heat/humidity buildup in BIP RAs, NIOSH performed a series of heat/humidity tests on a 60-person BIP RA with and without a borehole air supply. At various times during the year, tests were performed with cooled and heated borehole air and unconditioned borehole air to examine how various outdoor temperatures may affect the thermal conditions inside a BIP RA. The results show that the air supplied to a BIP RA may require heating and cooling, depending on the outside air temperatures and the temperature of the mine. For example, during tests with an external ambient temperature above 70°F and a humidity that reached 90%RH, providing 55°F dew point air was able to keep the internal apparent temperature below the mandated 95°F. Results for each test case will be presented.

3:25 pm

Cryogenic Breathable Air Supply/Heat & Humidity Mitigation System for RA

E. Blalock; Private Contractor, Titusville, FL

For underground coal mines, heat buildup inside an occupied RA/BIP is a serious concern especially where ambient mine temperatures are routinely at or above 24°C (75°F). In addition, relative humidity approaching 100% is expected inside an occupied refuge. Without a means to dissipate the heat and humidity generated by the occupants and the carbon dioxide scrubbing system, the temperature and humidity inside an RA or BIP could lead to severe discomfort, heat stress or worse, depending on the initial inside temperature which is directly related to the mine ambient temperature. An effective heat and humidity mitigation system will enable miners to use RAs and BIP shelters at their design capacity instead of derating their occupancy, in some cases by as much as half. CLSS has developed a comprehensive “RA Cryogenic Air Supply & Cooling System” in preparation for the execution of CDC BAA Number: 2016-N-17685 “Refuge Alternative Heat Mitigation System Utilizing Advanced Liquid Air Technologies”.

TUESDAY, FEBRUARY 21

AFTERNOON

2:00 pm **Room 708**

Coal & Energy: Unconventional Energy: CBM, CMM, and Shale Gas

Chairs: *N. Ripepi, Virginia Tech, Blacksburg, VA*
N. Gupta, Virginia Tech, Blacksburg, VA

2:00 pm

Introduction

2:05 pm

Opportunities for Recovery and Use of Methane from Abandoned Underground Coal Mines

F. Ruiz[1] and M. Cote[2]; [1]Climate Change Division, U.S. Environmental Protection Agency, Washington, DC and [2]Ruby Canyon Engineering, Grand Junction, CO

The economic value of coal mine methane (CMM) can be extended well past the time of abandonment of underground coal mines. Abandoned mine methane (AMM) projects, while smaller in size than CMM projects, have proven to be a stable, long-term source of methane for energy projects. Most or all of this methane would eventually reach the atmosphere through fugitive emissions, thus projects can also be important GHG emission reduction projects. Given methane's high global warming potential, GHG emission reduction credits generated by AMM projects can add an important revenue stream. Since the 1990s a number of AMM projects have been developed in Germany and U. K. generating hundreds of MW of electrical and thermal energy. Currently, there are about 20 AMM projects operating in the U.S., mostly selling AMM to pipelines. As the restructuring of the coal industry continues in the U.S. and more gassy mines close, AMM project opportunities will increase. This presentation will focus on AMM as a proven energy source and U.S. project opportunities, as well as highlight the U.S. EPA's Coalbed Methane Outreach Program's role in assessing and promoting AMM project development worldwide.

2:25 pm

Composition Analysis of Coalbed Methane from the Central Appalachian coalfields

X. Tang[1], N. Ripepi[1], A. Louk[1], S. Keim[2] and M. McClure[2]; [1]Department of Mining & Minerals Engineering, Virginia Polytechnic Institute & State University, Blacksburg, VA and [2]Cardno, Bluefield, VA

Coalbed methane (CBM) components are analyzed in the Central Appalachian coalfields to see how the CBM components change with desorption time and coal seam depth. Gas samples are obtained directly from a desorption canister of each coal seam that was collected during vertical core drilling. Each gas sample is obtained subsequently at different times from desorption canisters using vacuum Serum-separating tubes during the desorption gas measurement process. Gas samples are analyzed using gas chromatography-mass spectrometer for C_1 to C_5 hydrocarbons and for carbon dioxide. Test results show that both methane and carbon dioxide content decrease with time in the desorption canister while heavier hydrocarbons (C_2-C_5) tend to increase. Gas samples from deeper coal seam contain more heavier hydrocarbons.

2:45 pm

Adsorption and Desorption Behavior of Methane in Marcellus Shale

X. Tang and N. Ripepi; Department of Mining & Minerals Engineering, Virginia Polytechnic Institute & State University, Blacksburg, VA

Shale gas recovery from shale formations is a desorption process driven by reservoir pressure depletion. However, methane adsorption isotherms in shale are routinely used for shale gas resource estimation and developing shale gas transport models rather than the desorption isotherm. The difference between the adsorption and desorption isotherms and how this difference will influence the shale gas recovery have rarely been considered. This work conducts methane adsorption and desorption tests using a volumetric test approach under different temperatures and maximum equilibrium pressures to investigate how temperature and equilibrium pressures will influence the adsorption and desorption behavior of methane in shale. The influence of equilibrium time on adsorption and desorption isotherms will also be considered. The findings of this study will be fundamental for accurately estimating the shale gas resource and investigating gas sorption effect on shale gas transport behavior.

3:05 pm

Modeling of CO2 and Tracer injection in Deep Unmineable Coal Seams

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

Carbon sequestration is the process of capturing and storing carbon dioxide (CO2) in order to mitigate carbon dioxide emissions. One of the carbon sequestration options is geological storage of CO2 in deep unmineable coal seams. Coal prefers adsorbing CO2 to methane therefore CO2 injection into coalbeds can enhance natural gas production, while at the same time mitigating CO2 emissions. CO2 plume movement within the reservoir can be estimated using tracer gases by monitoring the arrival times and concentrations at offset wells. In this paper, CO2 and tracer injections were modeled together in a reservoir simulator to estimate CO2 plume and tracer movement. The reservoir model was created based on real data collected from an ongoing US Department of Energy funded pilot project. As a part of the ongoing pilot project, up to twenty thousand tonnes of CO_2 is planned to be injected into three vertical coalbed methane wells over a one-year period in Buchanan County, VA. Tracer gas concentrations at offset wells predicted by the model were compared with field data.

3:25 pm

Interaction between Proppant Packing, Reservoir Depletion, and Fluid Flow in Pore Space

M. Fan[1], J. McClure[3], Y. Han[2] and C. Chen[1]; [1]Mining Engineering, Virginia Tech, Blacksburg, VA; [2]Petroleum Engineer, Huston, TX and [3]Advanced Research Computing, Virginia Tech, Blacksburg, VA

In the oil and gas industry, the performance of proppant pack in hydraulically created fractures has a significant influence on fracture conductivity and, ultimately, oil recovery. In this research, a numerical modeling approach, combining Particle Flow Code (PFC) and GPU-enhanced lattice Boltzmann simulator (GELBS), is adopted to advance the understanding of the interaction between proppant particle packing, depletion of reservoir formation, and transport of reservoir flow through the pore space. In this numerical work flow, PFC is used to simulate effective stress increase and proppant particle movement and rearrangement under increasing mechanical loading. The pore structure of the proppant pack evolves subsequently and the geometrical data are output for lattice Boltzmann (LB) simulation of proppant pack permeability. The proppant pack permeability as functions of effective stress and porosity is investigated, showing that the proppant pack with a higher proppant diameter coefficient of variation has lower permeability and porosity under the same effective stress. Relative permeability curves are also obtained using multiphase LB simulation to study non-wetting phase trapping.

3:45 pm

Modification of Coal Failure Criteria Incorporating Anisotropy and Sorption Characteristics of Coalbed Methane Reservoirs

S. Saurabh and S. Harpalani; Southern Illinois University, Carbondale, IL

The phenomenon of in situ coal failure is commonly encountered in deeper coalbed methane (CBM) reservoirs after substantial depletion, resulting in creation of new fractures/cracks. Whereas these provide additional flow paths for gas, failure is often accompanied by production of fines and coal rubble, requiring time consuming and expensive well cleanouts as well as temporary drop in permeability. This paper presents the various coal failure criteria, modified for application to CBM reservoirs since most theories have been developed for isotropic and non-sorptive rocks. For CBM reservoirs, a model is proposed that takes into account the unique behavior of gas transport in coal, namely anisotropy, adsorption stresses and triaxial stress conditions. The model for in situ failure is validated using experimental data obtained in a pressure-dependent-permeability study completed for San Juan coal. The data included sorption and matrix shrinkage characteristics, geomechanical testing for Young's modulus, Poisson's ratio and failure envelope, and changes in permeability with continued depletion. There was excellent agreement between the experimental data and the proposed model.

4:05 pm

Changes in Gas Storage, Transport and Mechanical Properties of Coal with Continued Microbial Bioconversion

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

This paper discusses the preliminary work aimed at imitating the microbial process of biogenic gasification of coal as a means to recharge depleted coalbed methane (CBM) reservoirs and/or increase their gas content. Preliminary results using coal fines have shown that the sorptive capacity and diffusion of gases in coal improve considerably post-treatment. In order to move forward with commercialization for in situ applications, changes in transport/mechanical properties of coal are being currently evaluated. At this time, permeability behavior of solid coal is being investigated for helium flooding pre- and post- microbial treatment. It is expected that changes in porosity post-treatment would result in increased permeability and, hence, significantly impact the commercial viability of the technology. Variation in the permeability trend with decreasing pore pressure, before and after bioconversion, would establish mechanical changes in the coal fabric. Finally, SEM imaging of coal would reveal the microbial access to coal microstructure.

TUESDAY, FEBRUARY 21

AFTERNOON

2:00 pm Room 102

Environmental: Compliance and Permitting

Chairs: *L. Stegink, Barr Engineering Company*
D. Heinze, ENVIRON International Corp., Denver, CO

2:00 pm

Introduction

2:05 pm

Financial Assurance, Closure Cost Estimates and Asset Retirement Obligations for Mining Projects – Different Numbers for Different Reasons

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

Within the last 20 years, mine closure liabilities represent an increasing proportion of the balance sheet of a mining company. This presentation examines regulatory trends related to closure obligations in the Americas as well as financial disclosures by public mining companies with regard to asset retirement obligations and environmental liabilities. Regulatory trends include national and, where applicable, regional (e.g., provincial, state) governmental regulations that monitor and revisit mine permitting requirements. In North and South America, the sharing of experiences related to mining legacy issues triggers regulatory revisions at a national and/or international basis. In addition to permitting trends, international accounting standards recognize reclamation and closure obligations of public mining companies by estimating Asset Retirement Obligations through use of financial models. Whether a mining company is audited under U.S. Generally Accepted Accounting Principles or International Financial Reporting Standards, accounting firms demand a fair-value estimate of the legal closure obligation for each mining property.

2:25 pm

The Effects of CERCLA 108(b) on US Mining Operations

G. Davis[1] and P. Yang[2]; [1]Economics and Business, Colorado School of Mines, Golden, CO and [2]China University of Petroleum, Beijing, China

CERCLA 108(b) is a new rule under the EPA's "Superfund" whereby hardrock mining operations will be required to post financial assurance for reclamation beginning in 2018. The amount of assurance at each site will be proportional to the quantity of polluting "facilities" such as heal leaches and tailings dams at the end of the mine life. The EPA is hoping that by making the financial assurance proportional to the quantity of polluting facilities the rule will incentivize firms to reduce the quantity of pollution generated. The use of financial incentives to regulate mine pollution is novel, as in the past regulation has been via environmental standards. Our paper models the incentives inherent in 108(b). To the extent that pollution abatement activities are available firms will make use of them in order to reduce the financial assurance required. This meets the EPA's wishes. On the other hand, the mere requirement of reclamation may still not ensure positive social benefit from a mining operation when there are ongoing pollution damages while the operation is underway. Heavy metal contaminaton of the farmlands surrounding China's coal mines is an example where this is possible.

2:45 pm

Gates & Schedules in Permitting: the Waste Characterization Program

M. Ciardelli, A. Haus and J. Lynott; Foth Infrastructure & Environment, LLC, De Pere, WI

Mine permits require that potential impacts to the environment resulting from mining activities, particularly water quality impacts associated with acid rock drainage (ARD) and metal leaching (ML), be clearly delineated and mitigated. During the mine permitting and planning processes, waste characterization programs are used to determine potential ARD and ML, and subsequent geochemical modeling is utilized to support the design of appropriate methods for managing waste rock, tailings, and contact water. Waste characterization is a critical but time-consuming step; changes in the mine plan have the potential to "reset the clock" here. To avoid delays in permitting related to waste characterization programs, the programs must be designed such that changes in mine planning can be accounted for. This presentation will demonstrate how changes in mine planning can impact waste characterization programs and the permitting schedule if not properly accounted for and managed, and also suggest some tools and solutions.

3:05 pm

Cyanide Recovery from Barren Solution Using UV Photodissociation and Gas Filled Membrane (GFM) Technology

K. Banerjee and H. Buisson; Veolia Water Solutions and Technologies, Moon Township, PA

A process was developed to recover cyanide from barren solution containing simple and metal-cyanide complex. The technology includes pretreatment of metals and oxyanions, UV-light-aided photodissociation of metal-cyanide complex, and Gas Filled Membrane (GFM). Using a 200w medium pressure UV light at 254nm wave length, more than 85% cyanide ions (CN^-) were recovered from soluble iron cyanide complex at pH between 10.0 and 10.5 within one hour of reaction. The effluent from the UV reactor was filtered and pH was adjusted between 5.0 and 5.5 in a leak proof container, prior to pumping to the GFM that separated hydrocyanic acid (HCN^0) from water. Liquid solutions were pumped on the both sides of the membrane. One side contained hydrocyanic acid solution, and 1 N sodium hydroxide solution was recirculated on the other side of the membrane. Within one hour, more than 90% cyanide was recovered in the sodium hydroxide solution. The preliminary results including the impacts of pH, UV dosage, sequestering agent dosages, and reaction time on the photodissociation efficiency will be presented. Also, the impacts of temperature and membrane flux rate on the cyanide recovery will be disussed.

3:25 pm 17-127

Effects of Longwall Mining on Aquatic Resources at the Bailey Mine in Southwestern Pennsylvania

M. Shema[1] and J. Silvis[2]; [1]Ecological Services, Civil & Environmental Consultants, Inc., Pittsburgh, PA and [2]Consol Energy, Inc., Canonsburg, PA

Since 2005, longwall coal mine operators in Pennsylvania (US) have been required to collect extensive biological and hydrologic data to document pre- and post-mining conditions of aquatic resources overlying the subsidence control plan areas (SCPA). Continued operation of the longwall mine is dependent upon empirical data demonstrating that the undermined aquatic resources have either maintained or been restored to the normal range of pre-mining conditions. This presentation examines the extent to which aquatic resources (streams and wetlands) have responded to longwall subsidence at Bailey Mine, Greene County, Pennsylvania. Comparative biological metrics and quantitative hydrologic methods will be discussed in order to give a full perspective on the scope of change that is being realized. Overall, the hydrologic balance is being protected and the aquatic life use of streams has been maintained within the Bailey Mine's SCPA. Pennsylvania's stream protection requirements mirror those in the pending final federal stream protection rule, so the Bailey Mine example may foreshadow stream monitoring and mitigation requirements for the mining industry throughout the United States.

3:45 pm

Remote Sensing of Wetlands for Land Use Planning and Environmental Permitting

B. Tolcser and A. Kramer; Short Elliott Hendrickson Inc., Duluth, MN

The wetland permitting process can be cumbersome for large projects involving many site design alternatives or vast areas of landscape to evaluate. Remote sensing can be used as a tool during preliminary project planning and environmental review to identify wetland areas to be avoided or minimized for project site selection, placement of site infrastructure, and alternatives analysis. Better technology and newer, higher quality aerial imagery and LiDAR data make it possible to achieve a level of wetland mapping accuracy adequate for project site design alternatives analysis. This approach is more efficient than onsite field delineation and can provide substantial cost savings during environmental review by screening alternatives for potential wetland impacts. The presentation will cover a case study for a road design project in Minnesota. Remote sensing of wetlands was utilized throughout the project design phase to efficiently navigate the complexities of state and federal wetland permit processes including wetland delineations over a large spatial area, analysis of alternatives, establishing avoidance and minimization measures, and determining wetland jurisdiction.

4:05 pm

AERMOD Deposition Algorithm Method Selection and its Impacts on Fugitive Source Model Results

E. Edwalds, T. FASKING, j. bennett and J. Koenen; Barr Engineering, Minneapolis, MN

With any modeled exercise, the results determine regulatory project approvability. To that end, AERMOD dispersion modeling of fugitive dust sources at mining operations has been shown to significantly overpredict air concentrations. AERMOD includes two particle deposition algorithms (Methods 1 and 2) which can be used to calculate plume depletion (removal) and provide more representative modeled concentrations. Further, AERMOD includes a half-life (decay) term which can also be effectively used to represent plume depletion. This paper will highlight the differences between the methods and provide examples of how modeled air concentrations can vary based on the method and inputs chosen.

TUESDAY, FEBRUARY 21

AFTERNOON

2:00 pm **Room 104**

Environmental: Environmental Research

Chairs: *B. Greer, Solid Solution Geosciences, Louisville, CO*
B. Hanna, Itasca Denver, Inc., Lakewood, CO

2:00 pm

Introduction

2:05 pm

A Key Geochemical Variable Appears to Control Waste Rock Acid Generation

A. Davis; Geomega, Boulder, CO

Potentially acid-generating (PAG) waste rock has an acid-base accounting (ABA) ratio <1.2. At the Robinson Mine, Ely NV, 177 humidity cell tests (HCTs) run for up to 108 weeks supported a mine-specific PAG cut-off of 0.3 resulting in re-classification of 125 million tons of waste rock, allowing shorter haul distances and improved mine economics. At Mine B in Brazil, 343 profile and 33 surficial waste rock grab samples exposed to the elements for >8 years evinced a similar phenomenon, with a PAG cut-off of 0.4. At the Turquoise Ridge Joint Venture, NV the cutoff for 98 HCTs representing 10 separate lithologies ranges from 0.5-1.1. However, at Mine D, the ABA cutoff for 63 HCTs was 1.6, demonstrating the need for mine specific ABA ratios. 28 Hycroft HCTs also results in a 0.3 cutoff, while at the Marigold Mine, 574 pH waste rock and 31 HCT pH measurements with an ABA ratio >0.3 failed to generate sub pH-6 leachate. Post-mortem HCT mineralogy demonstrated that pyrite in waste rock with sub-1.2 ABA ratios was frequently encapsulated by quartz, while the perimeter surfaces of “nano-pyrite” particles exhibited secondary rinding by iron oxide thwarting the onset of acidification.

2:25 pm

Constructed Wetland Design and Optimization for Metal and Metalloid Treatment at the Minto Mine, in the Yukon, Canada

M. Haakensen, V. Friesen and R. Herbert; Contango Strategies, Saskatoon, SK, Canada

Results of 2 years of operation of a site-specific demonstration Constructed Wetland Treatment System (CWTS) developed for Capstone Mining Corporation’s Minto Mine (Yukon) will be presented. A scaled phased approach is being used to develop the full-scale system. Phases are: 1) site assessment and information gathering, 2)technology selection and conceptual design, 3)pilot-scale testing and optimization (controlled environment), 4)onsite demonstration-scale confirmation and optimization and 5)full-scale implementation. Highlights include application of modern day biogeochemical technologies such as microbial community profiling (MCP testing) to guide system design in a site-specific context. Pilot-scale studies selected the optimal design from several options and tested different predicted closure water chemistries. The selected designs are treating the water for the targeted constituents of cadmium, copper, and selenium, with polishing achieved for several additional metals. Removal rate coefficients were developed for modelling and sizing of full-scale systems.

2:45 pm

Making Business Decisions for Phosphate Mining Operations through Modeling

R. Davis; Cardno, West Valley, UT

The daily volume of water handled at a Florida Phosphate mine is great and on average it amounts to moving several hundred thousand gallons per minute of water around the property. Prudent management of the water 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 the mine. Historically, water management has relied upon human judgment of a few individuals, and while they have done a very good job, the industry faces ever stricter discharge limitations. To ensure a mine is properly positioned to comply with these limitations and a desire to further improve water management decisions, water balance models have been created for the phosphate mining industry. These models were created to determine if the complexities of an active phosphate mine and reclamation activities can be successfully reduced to mathematical simulations. The presentation will discuss how these models were created including all the parameters considered for inputs and outputs (ore mined, rainfall, evaporation, seepage, ground water use, beneficiation impacts, reclamation activities, etc.).

3:05 pm

Applying Mine Tailing as a Construction Material Using Geopolymerization for a Sustainable Development

J. Zhang and W. Zhang; University of Arizona, Tucson, AZ

In mining activity, the impoundment of mine tailing occupies a huge area of land and leads to high monetary, environmental and ecological costs. In present study, efforts have been tried to apply mine tailing as a construction material using geopolymerization for a sustainable development. Through the present investigation, a protocol to make construction materials using the mine tailings has been built up. The experiment results of present work also help optimize the working conditions such as activation temperature and time, the addition of NaOH, water glass and others, curing temperature and curing time. The findings of the present work provide a novel method for the geopolymerization of mine tailing as a construction material, such as bricks for construction and road pavement.

3:25 pm

Mineral Leaching Rates from a Tailings Deposited in an Intertidal Zone: Results from Kinetic Testing and Geochemical Modelling

R. embile[1], I. Walder[1] and J. Donatelli[2]; [1]EES, New Mexico Institute of Mining and Technology, Socorro, NM and [2]Kjeoy Research and Education Center, Vestbygd, Norway

Mine tailings from the Råna Nickel-olivine mine were deposited over a massive sulfide tailings deposit in the intertidal zone of the Ballangen Fjord, Norway. Leaching of metals (Ni, Cu, Fe) to the fjord has not been fully understood. Kinetic testing of the tailings material from the upper 2-3 feet of the tailings deposit was conducted for seventy weeks. A beach sand and creek sediment adjacent to the tailings deposit was also used. Weekly leachate data were used as input parameters in modelling mineral dissolution and precipitation rates using PHREEQC. Results from kinetic testing show spatial variation in pH and metals concentration within the tailings deposit. The tailings sample closest to the beach and to the western edge of the deposit generally have higher pH in the range of 5 to 7 while those closer to the creek (eastern edge) are more acidic with pH of 3 to 4. Cu is highest in the stream sediment, while the middle close to the stream has elevated Ni and Fe. All the metals analyzed (Ni, Cu and Fe) decrease in concentration in time. Elevated Mg^{2+} concentration suggests significant weathering of forsterite which is strongly correlated to the release of Ni.

3:45 pm

DEMET Electrolytic Neutralization: Economics and Treatment Options

P. James; Blue Planet Strategies, Madison, WI

DEMET technology's recently demonstrated and overviewed (SME-2015, SME proceeds 15-095) new capability to cleanly and cost-effectively electrolytically neutralize acidic MIW (Mining Influenced Waters) is examined in greater detail. Its general application to a variety of MIW sources considered and economic comparisons to conventional chemical neutralization approaches made. Economic and environmental benefits along with the treatment's potential to recover valuable revenue generating residuals from the MIW is discussed and estimated along with potential DEMET treatment options and practical considerations for situations of low to plentiful makeup water availability.

TUESDAY, FEBRUARY 21

AFTERNOON

2:00 pm **Room 709**

Environmental: INAP Presents Innovation in Closure Covers

Chairs: *C. Parnow, Newmont, Denver, CO*
G.Trembley, INAP, Australia

2:00 pm

Introductions

2:05 pm

Implementation of Risk-Informed Decision Making in Mine Water Management

J. Lupo; Newmont Mining Corporation, Greenwood Village, CO

Mine water management is critical to maintaining an effective and sustainable mine operation. However, mine water management plans are often developed based on a single set of assumptions or mine plans without regard to future or current risk. Risk enters into mine water management plans in the form of uncertainties associated with available or changing water resources, changing climate, changing mine plans, and social, environmental, and regulatory issues. A more robust approach to mine water management is to integrate Risk-Informed Decision Making (RIDM) concepts in to the development of water management planning. The RIDM approach is a process of making decisions by identifying and evaluating if existing risks are tolerable, if present risk measures are adequate, and if not, whether alternative risk reduction measures are justified. The RIDM has been successfully applied in the civil industry, but has limited exposure in the mining industry.

2:25 pm

Soil Covers and Sloping Surfaces

B. Weeks; Golder Associates Ltd., Vancouver, BC, Canada

The majority of the numerical codes that have been developed for the assessment of soils covers were developed considering 1-D infiltration scenarios. While these codes have been subsequently modified for 2 and 3-D analyses, these modifications have generally focused on effects that occur in the subsurface, and dynamics that affect the movement of moisture once it has entered into the 2 or 3-D mesh, and not on variations associated with different microclimates and exposure. This presentation provides an overview of the practical implications of factors that can be expected to vary in three dimensions, and linkages to geomorphic design and land use.

2:45 pm

Global Cover System Design Technical Guidance Document

A. Baisley, M. O'Kane and B. Dobchuk; O'Kane Consultants Inc., Calgary, AB, Canada

Confidence in cover system technology for the management of chemically reactive mine waste has advanced significantly in the past 20 years. The mining industry has a better understanding of the need to integrate site-specific, holistic designs that consider climate, hydrogeology, geochemistry, material characteristics, and material balance into final landform designs. Nonetheless, further advancements are required in design methodology, construction quality control, and performance monitoring. The International Network for Acid Prevention (INAP) funded the development of a new Guidance Document, the Global Cover System Design Technical Guidance Document. This document builds on previous technical guidance documents on cover system design, construction, and performance monitoring. In addition, it highlights the challenge industry often faces to demonstrate the value of cover systems in mitigating detrimental impacts that mine waste may have on the receiving environment. The significance of this issue is greatest when evaluating water management (quantity and quality) and water collection and treatment systems.

3:05 pm
Clash of the Titans – Father Time, Mother Nature and the Mine Waste Cover
M. Rykaart; SRK Consulting, Vancouver, BC, Canada

Mine waste covers are one of the many tools our industry use to mitigate against the post-closure impacts of mining. Based on the overall closure objectives for a site, mine waste covers are designed to fulfill a specific set of "functions" for a defined timeline. The success these covers to continue to perform the "functions" in accordance with design expectations, is subject to considerable different opinions, spanning the spectrum from optimism to pessimism. The reality is that mine waste covers are thin engineered membranes covering vast volumes of potentially problematic mine waste, subject to continuous evolution of physical and chemical properties. We are expecting these thin membranes to perform its intended "function" amidst an unrelenting and ever changing onslaught of forces from Mother Nature, over a time period most commonly defined as "indefinite". While Father Time may be indifferent to such timelines, cover practitioners need to be more realistic.

3:25 pm
Earthen Cover System Design Modification Following Field Performance Assessment
M. Phillip, R. Millett, K. Schapansky, R. Shurniak and M. O'Kane; O'Kane Consultants USA, Anaconda, MT

In 2012, an evapotranspirative cover system design field trial was constructed in southeast Idaho to demonstrate the design's performance in limiting net percolation into mine waste. Three years of monitoring consistently showed annual net percolation to be greater than predicted. Extensive data analysis shows that the net percolation increase is attributed to weather differences and greater than anticipated material evolution. Compared to the 100-yr record used to design the cover system, the monitored weather is warmer with a greater share of rainfall precipitation. This paper discusses the design of the cover system, its monitored performance and assessment, and redesign to remove infiltration as interflow or lateral percolation.

TUESDAY, FEBRUARY 21
AFTERNOON

2:00 pm **Room 108**

Environmental: Technologies for Management of Mining Influenced Water in Historic Mine Pools (ADTI-MMS)

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

2:00 pm
Introduction

2:05 pm 17-109
Risk Analysis for Evaluation of Mine Impounded Water

M. Gobla; Bureau of Reclamaiton, Denver, CO

Since 1994 the Bureau of Reclamation has used risk analysis to evaluate dams. Risk considers both the likelihood of failure and the expected consequences should failure occur. Risk analysis relies on the detailed formulation and critical analysis of all possible potential failure modes. A potential failure mode is formulated by describing the sequence of events that must occur to result in failure, where failure is defined as the uncontrolled release of the impounded reservior. Failure occurs in response to loadings such as water seepage through a dam (static forces), shaking from an earthquake (dynamic forces), sudden flood inflows (hydrologic forces), or accidental overfilling (operational errors). Reclamation has applied risk analysis methods to inactive and abandoned mines to evaluate tailings dams and flooded underground mines. Case histories of potential failure mode analysis as applied to mine impounded water illustrates what critical technical information is needed to determine if failure is likely, what the consequences of failure are likely to be, and what are the highest risks that should be addressed first.

2:25 pm
Developing Realistic Goals for Long-term Management and Remediation of Abandoned Mine Sites: Monitoring and Corrective Action based on Assessment of Risks

R. Breitmeyer and R. Thomas; Geological Sciences/Graduate Program of Hydrologic Sciences, University of Nevada, Reno, Reno, NV

The release of over one million gallons of mine-impacted water from the Gold King mine into the Animas River in 2015 provided a shocking illustration of the persitant environmental hazards posed by abaondoned mine sites. Current estimates put the number of abandoned mine sites with potential environmental hazards in the thousands across the Western United States. Given that many abandoned mine land (AML) sites are located on public land, and highly constrained agency budgets, there are not enough financial or human resources to fully remediate and eliminate all environmental hazards associated with AML sites. A risk-based approach to setting goals for AML remediation is presented which takes into account the relative risks posed by an AML site in long-term management and remediation strategy. An exampple of this risk-based approach is presented for the Perry Canyon AML site located in Washoe County, NV. Relative risk of the Perry Canyon AML is presented both from an environmental impact and potential cost of cleanup standpoint. Discussion of how long-term management strategies and site prioritization can be informed by this risk-based approach is also provided.

2:45 pm
Treatment of Mining Impacted Waters in Historic Mine Pools at the London Mine

J. Harrington; MineWater LLC, Northglenn, CO

MineWater has recently entered into a unique Consent Order with the State of Colorado for the remediation of the London Mine near Fairplay Colorado. The scope of the Consent Order includes the treatment of the historic mine pool impacted with cadmium, zinc and other contaminants, and resolves one of the largest penalties levied against a mine, on a monetary basis, by the Water Quality Division of CDPHE. MineWater through its affiliate MineWater Finance LLC has taken title to the Mine and is on track to redevelopment of the Mine including the unlocking of water rights that have been under-developed since 1986. In this presentation we will address the technical, regulatory and legal challenges of the remediation of the historic past-producing 1.2 million oz (gold) London Mine.

3:05 pm

3-Dimentional Imaging of Abandoned Underground Mine Workings with Borehole Sonar

M. Culig and N. Davis; Colog, Inc., Lakewood, CO

Understand the extent of old abandoned underground mine workings, shafts and voids are difficult to characterize especially if they are flooded. Borehole sonar has been used as a tool to help image the intersected openings and to map the 3-dimentional geometry. There is a growing environmental concern to try to remediate these underground storage bodies of contaminated water and to predict the impact if something within the mine fails. Drilled holes from the surface that intersect mine working are used to provide the necessary access to deploy the wireline based sonar profiling device. The profiling sonar probe houses a rotating multi-frequency acoustic head that measures the reflected travel distance. Imaging data are merged with orientation data and processed with SonarSHED™ for presentation. Once a void has been characterized other geophysical methods are used to further identify the water quality and horizontal/vertical flow parameters.

3:25 pm

Characterization of Historical Metal Mining Wastes for Potential Metal Recovery

K. Smith, P. Hageman and G. Plumlee; U.S. Geological Survey, Golden, CO

Historical metal mining wastes may contain precious metals or critical mineral commodities that represent untapped resources for recovery and reuse. Elemental concentrations can be quite variable among different mining waste samples due to the type of mineral deposit, type of host rock, mining and ore-processing techniques, types of mineral phases present that contain trace elements, and mineralogical variability that can occur within a single deposit. The U.S. Geological Survey has characterized about 100 samples from historical solid metal mining wastes to determine the degree to which they contain enriched concentrations of trace elements and metals, and how their enrichments vary as a function of mineral deposit type. Findings indicate that elemental concentrations determined in some deposit types, such as polymetallic veins, are quite variable. Consequently, the economic and technical feasibility of metal recovery needs to be evaluated on a case-by-case basis. Although metal recovery may not currently be economically viable, removal of some metals may reduce future liability and revenue produced through recovery can be used to offset treatment and disposal costs.

3:45 pm

Control of Groundwater Flow and Biogeochemistry with Hydraulic Plugs, Glengarry Adit, New World District, Cooke City MT

L. Kirk[1], s. Matolyak[2], A. Kirk[2] and M. Marks[3]; [1]Enviromin Inc, Bozeman, MT; [2]Geomin Resources, Inc, Bozeman, MT and [3]3Gallatin National Forest, Bozeman, MT

Use of grouting to control groundwater inflow with hydraulic adit plugs within the historically mined Glengarry Adit at Cooke City MT effectively reduced discharge by more than 95% and resulted in groundwater rebound that flooded underground workings. Significant improvements were noted in groundwater quality post-closure, driven by changes which resulted in increased alkalinity and precipitation of aluminum and iron-oxide minerals followed by metal sorption. Concurrent dissolution of jarosite produced temporary increases in iron- and sulfate-related TDS at closure. More recent changes in water quality suggest further evolution of chemistry within the flooded mine workings, with declining iron and sulfate concentrationssuggestion possible precipitation sulfide mienrals. Comparison of microbial communities characterized using 16S rRNA in the immediate post-closure and more recent mine pool offer insight into these changes. Overall, improved water quality supports the use of this approach in other mine closure settings.

TUESDAY, FEBRUARY 21

AFTERNOON

2:00 pm **Room 610**

Health & Safety: Collision Avoidance Technologies: Challenges and Applications for Surface and Underground Operations

Chairs: *J. Keyes, Salt Lake City, UT*
T. Ruff, NIOSH, Spokane, WA

2:00 pm

Introduction

2:05 pm

Safety: Collision Mitigation Technologies Empower Operators and Minimize Risk of Surface Mining Sites

M. Wood; Mining Worldwide Sales, Preco Electronics, Boise, ID

Surface mining presents unique challenges for equipment operators and the technology that supports day-to-day operations at the site. Operating in harsh conditions, operators of heavy-duty equipment rely heavily on the latest collision mitigation technology to save lives, reduce the severity of potential accidents, protect property and minimize risk. Mr. Wood will cover current MSHA standards, best safety practices, as well as technology solutions available today for OEMs and the aftermarket. Mr. Wood will look toward the future and share how the industry is changing and how it differs domestically in comparison to abroad. Key takeaways that the audience will receive about Collision Mitigation Solutions MSHA standards: Evolving role in shaping practices and equipment builds Challenges: Safety solutions need to ensure accurate alerts Technology: Critical role in the operation today and in the future OEM vs. aftermarket: What are the options for both markets? Integration: Introduction of open solutions to fit within existing equipment International vs. Domestic: How do they compare and differ?

2:25 pm 17-008
Alternate Technologies Applicable to Proximity Detection on Mobile Machines in Underground Coal Mines
P. Bissert, J. Ducarme, J. Noll and C. Jobes; NIOSH, Pittsburgh, PA

There have been 40 fatalities in underground coal mines between 1984 and 2015 where the victim was struck, pinned, or run over by a mobile machine (MM) such as a shuttle car, scoop or battery hauler. MSHA has issued a proposed rule requiring proximity detection systems (PDS) on MMs in an effort to prevent future fatalities. Currently approved PDSs use electromagnetic (EM) technology to detect the presence of a miner and impose machine controls to prevent contact. The disadvantages of an EM-based PDS on MMs include the miner-wearable component, environmental interferences, EM interferences from other devices, and localization range & accuracy. NIOSH researchers are investigating alternate technologies that could mitigate these deficiencies. Many technologies were reviewed, and NIOSH researchers identified RFID, LiDAR, RADAR, ultrasonic detection, and computer vision as candidates for PDS development. The performance characteristics of each technology and its applicability to an underground mining environment will be discussed, along with international developments and implementations, and the concept of sensor fusion.

2:45 pm
Mining Safer Together: Stronger Collision Avoidance Through Integrating Contextual FMS Data
J. Clarke and D. Wells; Wenco International Mining Systems, Seattle, WA

Safety remains a major concern of the mining industry. Research from groups such as the Earth Moving Equipment Safety Round Table (EMESRT) has helped to establish best practices for operating heavy equipment in a safe manner. EMESRT recommendations contribute to equipment and software designs that reduce fatalities, injuries, and occupational illnesses associated with mining equipment. Many collision avoidance systems incorporate logic based on these recommendations to sort real safety hazards from benign proximity events. Although this technology functions with greater efficacy than previous systems, it does little to address a persistent issue inherent to any rule-based proximity detection logic: false positives due to missing contextual awareness. Integrating collision avoidance systems with fleet management data adds this necessary context. Equipment status, elevation, and other parameters collected by a real-time fleet management system can affect the severity of hazards found through a collision avoidance system. This paper discusses the impacts to mining safety that arise as a result of incorporating contextual fleet management data into collision avoidance logic scenarios.

3:05 pm
Integrating Mine Operations with Collision Avoidance
M. Romero; Hexagon Mining, Tucson, AZ

In the modern mine, safety is an essential part of daily operations which has caused the industry to see a steady increase in providers of safety solutions including collision avoidance (CAS). What has largely been missing has been a robust integration with fleet management system (FMS) solutions. This technology gap has meant more clutter in operator cabins, different office applications for vehicle safety and fleet management, and a lack of ability to analyze the relationship between safety and production. In this presentation we will provide an overview of how Hexagon Mining has successfully integrated CAS into its FMS system, strengthening both operations and safety.

We will delve into the integrations in both light and heavy equipment as well as office applications and reporting. Through this integration, both light and heavy equipment can be monitored online allowing better analysis of near-miss events, including the behaviors and conditions that cause them. Additional, safety and production can be monitored within one system reducing clutter in the control room creating a more transparent monitoring environment. Development and initial deployment results will be discussed.

3:25 pm

Proximity Detection with Reduced Nuisance Alarms, Purpose-Built for Underground Hard Rock Mines

A. Cervinka and C. Younes; Newtrax, Montreal, QC, Canada

The ultimate safety goal for mining companies is achieving a zero-incident work environment. One issue that consistently ranks as a major risk by the mining industry is the potential for collisions between underground mobile equipment and pedestrians. Using sub-GHz RF technology to form a peer-to-peer network of miners and vehicles, Newtrax has developed a proven technology to detect pedestrians around corners, and in blind spots that cannot be covered with other technologies. Consistently and accurately distinguishing passengers from pedestrians is a common problem in proximity warning systems. Due to the pervasive nature of RF, these systems typically cannot differentiate between a passenger inside the vehicle and a pedestrian standing just beside it. The patent-pending solution to this problem that Newtrax has devised can reduce the noise from these nuisance alarms by 90-95% for a more accurate and reliable system that ensures the safety of miners working underground. This case study will examine how Fresnillo's Juanicipio Project, a silver mine in Mexico reduced the number of near-miss incidents as well as lost time with this system.

3:45 pm

Pilot of a Collision Avoidance System at Barrick's Cortez Mine

C. Erickson; Engineering, Barrick Gold Cortez Mines, Elko, NV

A pilot of Hexagon Mining's SAFEmine Traffic Awareness and Collision Avoidance System was conducted on surface mining equipment and light vehicles at Barrick's Cortez operation in Nevada. The SAFEmine system determines vehicle location and movement information using GPS, while peer-to-peer radios are used to communicate this information to surrounding vehicles. The addition of TrackingRadar on haulage equipment and water trucks enable detection of untagged objects such as people or vehicles without the GPS-based system. The technology provides an integrated system that combines the GPS-based vehicle tracking information with TrackingRadar to monitor blind spots. The pilot was designed to evaluate the effectiveness of SAFEmine in increasing operator situational awareness and providing warnings of potential collisions on a large scale (300 vehicles). The systems' capabilities to share data and present SAFEmine collision avoidance and vehicle tracking information on the Leica Fleet Management System will also be evaluated. Pilot methodology and key performance indicators, along with results and recommendations, will be discussed.

TUESDAY, FEBRUARY 21

AFTERNOON

2:00 pm **Room 612**

Health & Safety: Improving Your HSMS: Best Practices, Metrics, and Lessons Learned

Chairs: *T. Hethmon, University of Utah, Salt Lake City, UT*
J. Seiter, Bowie Resources Sufco Mine, Bountiful, UT

2:00 pm

Introduction

2:05 pm

Leveraging Generational Differences to Enhance Workplace Safety

R. Jameson and S. Ratliff; Consulting, Danville, KY

The landscape of the American workforce is changing. Based on a recent analysis by the Pew Research Center, Millennials have surpassed both Baby Boomers and Generation X as the largest working generation. Furthermore, a recent Gallop Poll indicates that nearly 50% of Baby Boomers plan to continue working beyond the age of 65. Consequently, employers will soon be facing the most generationally diverse workforce in American history, and many companies are already confronting the challenge of managing two distinct groups of workers, Baby Boomers and Millennials, with completely different views of life, work, and the world in general. Based on the mainstream stereotypes surrounding each of these generations, this can seem like an impossible task. If not addressed and managed properly, these differences can result in devastating consequences for any company's safety management system; however, with the correct understanding and a pro-active approach, these differences can actually be leveraged to advance the workplace and enhance employee safety.

2:25 pm

Culture Always Trumps Your Risk System – So What Can You Measure to Take the Right Actions. A Case Study Demonstrating a Leading Indicator of Culture and Risk System Strength

E. Alexander; HSE, Saskatoon, SK, Canada

Companies known for the strength of their risk and safety management systems continue to experience significant incidents, and in some cases catastrophes. It is only when leadership, culture and systems work in complete harmony that the resilience of an organization to manage its significant risk is at an optimal level. And even then, it is a precarious balance to maintain that optimal mindset in the organization. A case study is presented that demonstrates how the maturity of the company's risk systems and safety culture have been benchmarked against a global data base of companies.

The risk maturity model and the scientific basis of measurement of culture are presented. The case study will demonstrate the practical application of the approach, and how the outcomes of the study provide input to leadership to make the necessary changes to the culture and the risk systems. All before significant events strike. It will also highlight how the process provides input to companies which enables them to build systems that are more robust. The presentation will appeal to those who want to use culture and risk system maturity to maximize the performance of their risk management systems.

2:45 pm

Safety and Health Management Systems: a Comparison of Structural Elements

J. Seiter; Safety, Bowie Resources Sufco Mine, Bountiful, UT

A review of the limited literature on SHMS provided a justification for a concept to elaborate on the structure of SHMS and the determination of a modern benchmark for future SHMS structural research. As a basis for the procedure an initial benchmark list of SHMS structure elements was determined to exist in the Dalrymple Scheme presented by Redinger and Levine in the late 1990s. The Dalrymple Scheme is considered to be a universal occupational safety and health management system (OHSMS) model, composed of 27 structural elements, assigned respectively to one of five categories. Next for the establishment of a modern benchmark, a list of additional SHMS structural elements was determined through analysis of the National Mining Association (NMA) management system, CORESafety. The analysis determined the need for seven additional SHMS structural elements to be included with the Dalrymple Scheme for a modern benchmark. The objective for this report is to demonstrate the application of the CORESafety structural elements for the use as a modern benchmark for SHMS structure research. The proposed benchmark was compared to seven globally recognized SHMS and 10 mining industry specific SHMS.

3:05 pm

Cost of Accident Analysis in Surface Mining Operations – a Case Study

K. Bansah[1] and M. Kubi Appiah[2]; [1]Mining Engineering and Nuclear, Missouri University of Science and Technology, Rolla, MO and [2]African Mining Services, Tarkwa, Ghana

Accidents can be costly due to injuries, damage to equipment, fines and legal fees, compensation claims, loss of employee morale and skilled personnel, and loss of corporate image which can result in crippling industrial growth. In this paper, accident data from February, 2014 to December, 2015 obtained from African Mining Services (AMS) at AngloGold's Iduapriem mine at Tarkwa in western Ghana were analyzed to assess the direct and indirect costs of accident. Additionally, insured and uninsured costs were analyzed to estimate the impact of accident on revenue. The maintenance department was observed to have recorded the highest number of injury incidents while load and haul recorded more damage incidents. Devoting more resources to high risk operational areas would improve safety and mitigate accidents.

3:25 pm

Identified Best Practices for Optimizing Data Management in a Health and Safety Management System

W. Rogers[2], M. Nelson[1] and P. Guild[1]; [1]Mining Engineering, University of Utah, Salt Lake City, UT and [2]Mining Engineering, University of Utah, Salt Lake City, UT, Afghanistan

Many HSMS suffer from high levels of redundancies which manifest themselves in a variety of ways; duplicate processes, forms, permits, and tracking mechanisms. These redundancies have severe impacts on the overall system and absorb critical "culture energy". The root cause of many of these breakdowns is a lack of proper data management and HSMS integration with other initiatives. A land mark study initiated by the University of Utah and sponsored by the Alpha Foundation is being conducted studying the effectiveness of HSMS across 16 different mining companies. A large amount of data is being captured which characterizes elements of HSMS and correlates their impact on safety outcomes. Two variables being assessed are the overall integration of the HSMS in process improvement and data management. A wide variety of approaches were seen through the study. A series of case studies are presented which develop some specific best practices for proper data management and integration of HSMS.

3:45 pm

Hazard Identification and Risk Analysis of Fire and Explosion in Underground Coal Mines

M. Shriwas and A. Jha; Mining Engineering, University of Utah, Salt Lake City, UT

Historically, fire and explosions have been major causes for fatality in underground U.S. coal mines. On Dec 19, 1984 Wilberg mine fire resulted into 27 fatality. On April 5, 2010 Upper Big Branch mine explosion resulted into 29 fatality. Investigation reports show that such event could have been prevented if hazards were identified and associated risks were analyzed to develop and execute control measures. The methodology included reviewing the investigation reports and published papers to identify contributing factors that resulted into fire and explosion. This study used two risk tools - Workplace Risk Assessment and Bow Tie Analysis- to analyze the corresponding risk. As a result of this study, guidelines and control measures were developed to reduce the number of fires and explosions. This paper provides an insight to comprehend the nature of fire and explosion in underground coal mines.

TUESDAY, FEBRUARY 21

AFTERNOON

2:00 pm **Room 110**

Industrial Minerals & Aggregates: Health and Safety

Chairs: *P. Roghanchi, University of Nevada, Reno, NV*
A. Jolly, SME Member

2:00 pm

Introduction

2:05 pm

Time Series Analysis and Statistical Visualization of Fatalities and Citations in Sand and Gravel and Stone Mine Operations

P. Roghanchi[1], E. Tarshizi[2], L. Brown[3] and K. Kocsis[4]; [1]Mining Engineering, University of Nevada, Reno, Reno, NV; [2]Department of Geological and Mining Engineering, Assistant Professor, Houghton, MI; [3]Department of Computer Science, Associate Professor, Houghton, MI and [4]Department of Mining Engineering, Associate Professor, Reno, NV

Mining occupational injuries and fatalities have significant social and economic implications for individuals, their families, and the industry. Despite the progress that has been achieved in reducing mining injuries and fatalities, both the number and severity of mining accidents occurring are still ameliorable. In this research, MSHA data from 2007 to 2015 was used to classify the fatalities based on the types of accidents in order to identify which types were most often involved in Sand and Gravel and Stone mining operations separately. Fatalities were also categorized by mine sizes, occupations, total experience, job experience, and age. A series of statistical and time series analyses were performed on the number of fatalities and violation citations in the aggregate and for stone mines to determine whether the violation citations could have relative impacts on the fatality trend in this period.

2:25 pm

Prediction of the Whole Body Vibration in Mining Truck Driver Seats Using Artificial Neural Network

J. Sattarvand[1], M. Rahim Del[2] and M. Mirzaei[2]; [1]Mining and Metallurgical Engineering, University of Nevada Reno, Reno, NV and [2]Mining Engineering, Sahand University of Technology, Tabriz, eastern azerbaijan, Iran (the Islamic Republic of)

The research is conducted to study the Whole Body Vibration (WBV) of the truck fleet operating at a Caoline mine during various operational conditions in order to identify critical causes of the low back pain health issues among truck drivers. For this purpose, Root Mean Squares (RMS) of the vibrations in different speeds, loaded weights and load distribution profiles inside the truck buckets at different haul road qualities are measured through instrumentations on truck body and driver seats. Then, vibrational health risk at all operational conditions is analyzed according to ISO 2631-1 standard. An

optimization model is constructed in the next step to enhance the working health condition of the drivers and artificial neural network (ANN) is used to predict the vibrational health risk of different scenarios. Results showed that the mining haul road quality, truck speed, and the materials distribution quality have significant effects on the WBV respectively, whereas the load weight had a negligible effect on RMS of the vibrations.

2:45 pm

Pre-shift Inspection Training for Industrial Aggregates using Serious Games

L. Brown, M. Peltier and M. Poulton; Lowell Institute for Mineral Resources, University of Arizona, Tucson, AZ

Motivated by MSHA's 24 "Rules to Live By," we are developing "serious games" to address three training objectives: 1) Improve workers' technical competencies in the site inspection process; 2) Facilitate efficient communication and understanding of related rights and responsibilities, within the operational structure of the organization; and 3) Augment workers' situational awareness during the course of daily job activities. In this talk, we will present a serious game for pre-shift inspections in sand, gravel, and cement that features a realistic gaming world and modular content. The game was developed in close collaboration with industry stakeholders and addresses many of the top 20 types of MSHA violations, ranging from high-risk guarding and ground control problems to relatively minor housekeeping issues. We will discuss important factors in the game design, as well as initial results and industry feedback. A virtual reality-enabled adaptation, using commodity VR headsets, will also be presented.

3:05 pm

An Affordable Mine Monitoring and Proximity Detection Tool for Aggregate Mining Operations

J. Sattarvand, V. Abdollahi and M. Badroddin; Mining and Metallurgical Engineering, University of Nevada Reno, Reno, NV

Proximity detection systems and mining equipment monitoring instrumentations are not normally utilized in aggregate mining operations due to the high capital cost involved in purchasing these technologies; however, a considerable number of loading and hauling machines are working in aggregate operations and the risk of fatal accidents seems to be higher than that of large-scale operations. The paper describes cons and pros of a new mobile applications-based technology developed for enhancing the operational safety of the truck drivers. The technology aims to decrease the complexities involved in current mine monitoring systems by designating all truck instrumentation to a conventional tablet and all data communications are done based on the mobile telecommunications infrastructures that dramatically decreases the production and installations costs. By knowing the position of all equipment and even personnel around a machine, the system sends required warnings to the related truck or loader drivers to take care of their surrounding objects. The system has been tested in a mine with the intensive foggy condition and has considerably improved the safety level.

3:25 pm

A Review and Evaluation of Mine Safety and Health Regulation in USA and Major Mining Countries

B. Abbasi; Golder Associates Inc., Reno, NV

This paper reviews Mine Safety and Health Regulation in USA, Australia, Canada and China. Mining operation is inherently risky. These risks, hazards and disasters are very similar in different mines. To improve working environment safety different agencies have developed strict and extensive set of laws and regulations and these systems share many attributes. Despite similarities between the separate systems of mining law, the disaster record is significantly and meaningfully varies. Several arguments have been made as to the cause of this, including geographical difficulties, Miner's training, and lack of up to date regulations the meet the needs of current mining operation. This article explores similarities and differences between the mining safety and health regulation in the major mining countries and introduces some of the key reasons in the gap in safety.

TUESDAY, FEBRUARY 21

AFTERNOON

2:00 pm **Room 112**

Industrial Minerals & Aggregates: Non Traditional Aggregate Sources

Chairs: *R. Winn, R.E. Janes Gravel Co, Slaton, TX*
S. Stokowski, TEC Services, Lawrenceville, GA

2:00 pm

Introduction

2:05 pm

Types of Non-Traditional Aggregate Sources – You Made Aggregate out of What?

M. Lee; Westward Environmental, Boerne, TX

We are all familiar with the standard sources for aggregates such as limestone, granite, sand & gravel and so forth. For most markets, sources are nearby and the availability of material isn't a concern. For the rest, locating and economically extracting naturally occurring materials isn't a given. Alternative sources for construction materials is a must have in order to keep costs in check. This presentation will look at different types of non-traditional sources being used to make different kinds of aggregates.

2:25 pm **17-121**

The Study of Utility of Tailings for Shotcrete Production

A. Bascetin, d. adiguzel and S. Tuylu; Mining Engineering, Istanbul University, Istanbul, Avcilar, Turkey

In recent years the fact that mining tailings cause serious environmental problems resulted in increasing number of studies about their disposal, storage and usability in various areas. Therefore the new studies about using the tailings for some purposes such as using in shotcrete or producing concrete have been increasing recently. The study is focused on applicability of tailings for producing shotcrete. Under this scope it is considered that mining tailings can bring many advantages in case of that they are used instead of sand, silt or fine aggregate in shotcrete applications. Most important advantages can be listed as decreasing shotcrete cost, decreasing amount if mining tailings to be disposed and the contribution to be provided on sustainable production of sources. In this study, effect of mining process tailings, which will be added to shotcrete mixture on various ratios to obtain required strength was investigated.

2:45 pm

Iron Ore (Taconite) Mining by-Product Materials as Aggregate

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

By-products and co-products generated by Minnesota's iron ore (taconite) mining industry – such as low grade overburden rock and tailings – have been a major focus of the University of Minnesota Duluth's Natural Resources Research Institute (NRRI). NRRI's efforts have shown that these materials can be a significant and environmentally sound source of high-quality aggregate for a variety of conventional and value-added applications. When considered within the context of the critical need for repairing, maintaining, and upgrading the nation's transportation infrastructure, these iron ore mining-derived materials can represent a significant alternative to traditional industrial mineral aggregate sources, inside and outside of Minnesota.

3:05 pm

Hydraulic Behavior of Recycled Asphalt Pavement (RAP) Materials Used in Highway Shoulders

B. Cetin; Iowa State University, Ames, IA

The objective of this study is to evaluate the hydraulic properties of RAP materials in shoulder applications collected from different locations in Maryland. In order to determine the hydraulic properties, a series of grain size distribution tests and bubble tube permeameter tests were performed on the samples. The results of grain size distributions indicated that the RAP samples collected from different locations within Maryland can be identified as well-graded sand sized with gravel sized material and poorly-graded sand sized with gravel sized material. The data also indicates that the hydraulic conductivity of as-received RAP can be classified as similar to that of conventional granular material with similar gradation; however, hydraulic conductivity is significantly influenced by the size distribution of the RAP.

3:25 pm

Product-Driven Assessment of Alternative Aggregates

S. Stokowski; TEC Services, Lawrenceville, GA

The optimum method to successfully develop products from non-traditional aggregate sources is to identify and then exploit unique features. Unique and valuable features are often: color, shape, specific gravity, reflectivity, crystalline texture, hardness, porosity, pH, chemical composition, and fire resistance. These features allow notntraditional aggregates to expand markets not served well by traditional aggregate sources. New aggregate products from non-traditional sources expand market share without negatively competing with traditional rock aggregate. Some non-traditional aggregate products currently in the market are: slate chips, shell, ceramic chips, rubber chips, brick chips, red dog slag, mica, bottom ash, and iron & steel slag.

TUESDAY, FEBRUARY 21
AFTERNOON

2:00 pm **Room 212**
International II

Chairs: *M. Gavrilovic, GR Engineering Services, Denver, CO*
R. Furey, MWH, Broomfield, CO

2:00 pm
Introduction

2:05 pm
What's Driving the Market?
R. Furey and A. Watson; MWH, Broomfield, CO

The mining industry is cyclical by nature and knowing where we are in the cycle can be extremely valuable! This presentation will provide a high level summary of the current global market, the market outlook as well as market drivers and what they mean. The presentation will also focus on a few commodities and some of the trends driving those markets.

2:25 pm
The ILO 169 Convention in Peru
M. Cedron; Mining Department, PUCP, Lima, Peru

The International Labour Organization 169 Convention on Indigenous and Tribal peoples issued in 1989 was ratified by the Peruvian government in 1994. However for different reasons it was not applied to mining projects until last year. This presentation deals with the difficulties encountered in the application of this Convention and the criticisms of it.

2:45 pm
The Importance of Community Agreements to Enable Mine Developments in Peru
D. Benavides; Minera IRL S.A., Lima, Miraflores, Peru

Minera IRL SA, developing the Ollachea gold project in Puno, Southern Peru, has entered into an agreement with the Ollachea Community that provides a level of ownership and participation by the local community. This ensures all parties are working to a common goal to achieve the construction and operation of the mine and processing facility, which will bring much needed jobs and training to the region.

3:05 pm

From Graduate Metallurgist to General Manager – Sharing My Story

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

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

3:25 pm

Mining and Agriculture: Big Opportunities for Peru's Development

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

Some Peruvian politicians have created a false dispute between mining and agriculture, both of which are fully compatible activities. Given this, we would like create a synergy because both activities are very important for the development of Peru. Agriculture exports are US$6 billion and growing 15% annually, with about 500,000 Ha. available for new irrigation projects. Therefore an investment of US$15 billion is required, and exports will reach US$20 billion within the next 10 years. Mining is an opportunity for Peru as we have reserves of more than 80 Mt of copper, 25 Mt of zinc, and important amounts of gold and silver. In 2016 Peru will produce 2.4 million tons of copper, and will become the second largest producer in the world. Mining and agriculture are very important because each generates more employment, more exports, and an increase in GDP.

3:45 pm

Mine to Mill Value Creation at CIL, Heap Leach Gold Mining Operations in Saudi Arabia

E. Sellers and S. Kanchibotla; JKTech, Brisbane, QLD, Australia

Sukhaybarat and Bulghah are two open pit gold 74 kilometres apart from each other. Ore is trucked between the operations with low grade ore processed in a heap leach at Bulghah while high grade ore is processed at Sukhaybarat via Carbon in Leach (CIL). A review found that it was critical to improve the technical skills at the mine and to improve throughput. Mine to Mill process improvements studies were carried out with consultants visiting the operations and site engineers undergoing training in Brisbane. Key value drivers on the mines were found to be increased throughput from process optimisation and increased fines as well as reduction of dilution, ore loss and waste costs. Fragmentation and processing modelling was combined to determine the effect of blasting on throughput. Blast model simulations indicated that good blast confinement could reduce gold loss by US$121,000 per blast. Option analysis identified a number of value improvement options that required increasing levels of capital. Opportunities with low capital expense offered a 29.3% increase in the gold production. More complex changes could provide an additional 23.9% increase.

4:05 pm

Nicaragua: a Mining Overview

P. Williamson; SRK Consulting US, Denver, CO

The Central American nation of Nicaragua has a long and intermittent mining history, dating back to the first commercial mine in the RAAN district in the 1880s and continuing with British and American companies up through the Sandinista revolution and Contra war (late 1978 – 1989). Nicaragua is one of the poorest nations in Central America, but the government is actively seeking to develop its extensive gold and silver mineral resources, which include low sulfidation epithermal ore deposits, porphyries and skarns. The main mining company in Nicaragua is currently B2Gold, which operates the El Limon and La Libertad mines. Numerous projects are in development, including Topacio (Oro Verde), La India (Condor Gold) and San Albino (Golden Reign). While the permitting process and mining/environmental regulations are still being refined, Nicaragua has the advantages of a mining favorable political environment, very low crime rate, and good infrastructure. The main challenges to mine development are strong anti-mining sentiment and extensive artisanal mining.

4:25 pm 17-040

Development of Flowsheet for a Low Grade Chromite Ore in Turkey

S. Ergun, I. Celik And O. Gulsoy; Mining Engineering, Hacettepe University, Ankara, Turkey

In this study, the studies to develop a flowsheet for a low grade chromite ore are presented. The existing concentrator had to be suspended due to the decreasing metal prices. The study commenced with mineralogy and liberation profile of the chromite. The valuable mineral is chromite and the major gangue mineral is lizardite together with small amount of brucite and calcite Heavy liquid tests were performed on different size fractions without any acceptable success. The concentration tests were performed using teetered bed separator(TBS) +shaking table, spiral concentrator+TBS+shaking table for different grind size. Based on the test results, 100% finer than 0.4mm was found to be optimum for grind size. Comparison of alternative circuits showed that the performance of both alternatives would be similar. A flowsheet was designed and operated for as 25 tph trial circuit in the existing plant. The results showed that the performance of the plant predicted was very close to the actual plant data. The paper describes the methodology used, presents the experimental data and actual performance figures.

TUESDAY, FEBRUARY 21

AFTERNOON

2:00 pm **Room 210**

Mineral Valuation II: Lessons Learned and Fundamental Issues

Chairs: *T. Knobloch, AIMA, Marietta, OH*
D. Collins, DLC Productions, Inc., Littleton, CO

2:00 pm
Introduction

2:05 pm
Panel Discussion - Sales Comparison Approach to Energy Minerals under Fluctuating Commodity Prices

J. Gustavson[1], R. Bate[2], R. Hart[3], S. Melbye[4] and R. Vass[5]; [1]Mineral Appraiser LLC, Boulder, CO; [2]John T. Boyd Company, Denver, CO; [3]HartPetro LLC, Charleston, WV; [4]Uranium Energy Corp., Corpus Christi, TX and [5]Gauley River Minerals, LLC, Morgantown, WV

Recent history shows drastic changes in energy mineral prices, making valuation adjustments from mineral sales at earlier sale dates to the present date problematic. The Panel covers valuation of the energy minerals of coal, oil, uranium and natural gas. Each Panelist will briefly cover 1) Price history of each commodity with reasons for price changes, 2) The Panelist's personal view of near term and long-term price trends, 3) Recent mineral asset (or company sales) with data, which are relevant for valuation, 4) Comparison units (acreage, resources, reserves, other), which are found useful for the Sales Comparison Approach, 5) His/her personal guidance for adjusting for commodity price from Date of Sale to Effective Date of valuation. The Panelists are: Coal, Richard L. Bate, John T. Boyd Company, SME; Oil, Robert N. Hart, HartPetro Global LLC; Uranium, Scott Melbye, Uranium Energy Corp., and Natural Gas, Rachel L. Vass, Gauley River Minerals, LLC. John Gustavson is the Moderator. The format will allow each Panelist to entertain 2 questions after each introduction. Additional questions and audience discussion will be deferred to the general discussion period after all introductions.

3:20 PM
Influence of Market Factors and Freight Logistics on the Valuation of Silica Sand Deposits Utilized for Frac Sand

E. Mudd[1] and M. Springer[2]; [1]Independent Consultant, Holmen, WI and [2]Spanish Flat Mining Company, Garden Valley, CA

With end markets often more than 1,000 miles from the mine site, silica sand deposits may appear to have comparable valuations when they are located in geographic proximity and are of similar geologic character. However, sand deposits which share physical attributes and are only several miles apart may support very different value conclusions. Significant departures in value for two similar sites may often be attributed to seemingly micro-scale differences in end-user requirements, deposit size, logistics capability and the local regulatory landscape. Silica sand that is used to hydraulically fracture oil and gas wells (frac sand) is typically shipped via truck or rail to the well site. Industrial sand may also be extracted from silica sand deposits to serve markets such as foundry or glassmaking where the quality, transportation and grain size distribution are entirely different from frac sand applications. Some facilities have the logistical capability to serve oil, gas and industrial markets. This paper describes seemingly small differences in logistics and market fundamentals that may have significant value implications for silica sand deposits serving frac sand markets.

3:35 pm

The Implications of the Use of a Single Financial Model in the Income Approach to Value

A. Stagg; Stagg Resource Consultants, Inc., Cross Lanes, WV

It is common in conducting mineral appraisals in which the standard of value is market value for the appraiser to develop a single discounted cash flow model as the basis for the opinion of value. Implicit in this technique is the assumption that there is a one hundred percent probability that the input used in constructing the model will occur. Upon even the most modest reflection, it should be evident that this is not going to be the case. The author's experience in working with those involved in mergers and acquisitions affirms the general use of multiple financial models in establishing a proposed purchase price, with various iterations of the financial model addressing uncertainty (or, risk) and the sensitivity of value to variations in the input. By definition, one would expect an opinion of market value to reflect the practices of market participants, and that the opinion thus would have addressed these issues. In this presentation, the author addresses the probabilistic technique in developing an opinion of market value using the income approach to value and provides examples of its use.

3:50 PM

Simplified Comparison of the Major Ore Reserve and Mineral Resource Classification Systems for Mineral Appaisers

R. Cameron; Robert Cameron Consulting, Black Hawk, CO

When conducting an appraisal or issuing an opinion of value, it is important to understand the resource or reserve classification used in technical reports and how they relate to the the framework of the valuation code being utilized. This paper will present a simple guide that can be used to help an appraiser to properly understand and evaluate the reported resource or reserve classification assumptions. Although the various resource and reserve reporting standards around the world are constantly changing, an understanding of the broad principles discussed will help the appraiser to better set a value on the mineralization being reviewed.

TUESDAY, FEBRUARY 21
AFTERNOON

2:00 pm **Room 503**

Mining & Exploration: Geology: Resource Modeling

Chairs: *M. Moore, Maptek, Golden, CO*
M. Bourget, Maptek, Golden, CO

2:00 pm
Introduction

2:05 pm
Geological Modelling and Resource Estimation for Pilbara Iron Ore Deposits
E. Ronald; Rio Tinto, Perth, WA, Australia

Rio Tinto, operates 15 mines, four port terminals, and over 1,700 km of rail in the Pilbara regional of Western Australia. During H1 2016, production run-rates achieved over 330 Mta of shipped ore to customers. To support operations and provide future sustainability, RTIO maintains a robust program of resource evaluation, modelling, and estimation. Over 160 models are maintained with ~40 model updates annually supported by drilling programs of 600+ km per annum. Geological modelling uses implicit and explicit methods with focus on stratigraphic boundaries, structural complexity, mineralisation boundaries, and geometallurgical properties. Estimation is performed on ten chemical variables, density, material types, and Mineral Resource classification for public reporting. Deposits require testing of spatial continuity, neighbourhood analysis, with the common estimation method being Ordinary Kriging. In particular cases, non-linear estimation such as Indicator Kriging and Uniform Conditioning are available to improve estimates. A reconciliation system is maintained using blasthole data to validate the geological model and estimation techniques against actual mine production.

2:25 pm
Grade and Tonnage Uncertainty Analysis of a Copper Deposit from Africa Using Multiple Point Geostatistics and Sequential Gaussian Simulation
S. Chatterjee and A. Paithankar; Department of Geological and Mining Engineering and Sciences, Michigan Technological University, Houghton, MI

Spatial uncertainty analysis is complex and difficult for orebody estimation in mining industry. Conventional models with variogram-based statistics fail to capture spatial complexity of orebody. In this situations, tonnage and grade are often over- or underestimated, resulting in inaccurate mine plan that lead to costly financial decisions. The multipoint geostatistical simulation model can overcome the limitations of the conventional two-point spatial models. In this study, multiple point geostatstical method namely Snesim was applied to generate multiple equi-probable orebody models for a copper deposit from

Africa, that helps to analysis the uncertainty of ore tonnage of the deposit. The grade uncertainty was evaluated by sequential Gaussian simulation within each equi-probable orebody models. The results are validated by reproducing the marginal distribution, and two- and three point statistics.

2:45 pm

Tuning of Ordinary Kriging Parameters to Accurately Portray a High Variance Gold Deposit

J. Ruffini; Geology, Coeur Mining, Juneau, AK

The use of Ordinary Kriging to estimate mineral resources is a widespread technique but can be inadequate due to the degree of smoothing it produces, especially in a deposit with a high variance such as a gold deposit. Coeur Alaska's Kensington mine is an orogenic gold deposit in Southeast Alaska, located 40 miles north of Juneau. The deposit is defined by erratic extension vein arrays with highly variable sulfide mineral content, which contains the majority of gold. Historically, an Ordinary Kriging estimate has been ineffective at predicting the global resource and reproducing local variability for this deposit due to its high variance. It is possible to obtain strong production reconciliation and prediction of future infill drilling values by using appropriately tuned estimation parameters such as capping and high grade restrictive search ellipse and an effective geologic model defining the true orientation of continuity and employing subdomains.

3:05 pm

A New Paradigm to Manage Geological Risk in Mining

M. Godoy; Technical Services, Newmont Mining Corp, Greenwood Village, CO

At Newmont Mining, risk management is critical to delivering our strategy to improve the underlying business, build a stronger asset portfolio and differentiate ourselves from competitors. A new resource risk management process is creating a paradigm shift at Newmont, allowing us to minimize risks and capture opportunities more reliably than ever before. While we cannot control gold price, we can narrow the gap in our estimated and actual tonnages and grades, metallurgical recoveries, costs and productivity. Furthermore, the application of recent developments in the field of stochastic optimization will allow us to unlock additional value from our deposits and further enhance our ability to succeed in all commodity cycles.

3:25 pm

Development of a short range planning model for Kinross Gold Corporation's Kettle River - Buckhorn Mine

G. Moore and M. Olson; Geology, Kinross Gold Corp, Red Lodge, MT

The Kinross Gold Corporation's Kettle River-Buckhorn Mine has been in production since 2008. Throughout the mine life, significant annual fill-in and exploration core drilling continued, necessitating annual block model updates through the end of 2012. In 2013, the technical services group identified that more timely block model updates were required. Quarterly, all 3-D models of lithology, structure, and gold zones were updated to include diamond drill hole data, as well as insights gained through underground face mapping and production samples (channel samples and test holes), but the production samples were never included in the estimates. In March of 2016, the last resource block model was built and a new methodology was implemented to efficiently provide for an updated monthly model for short range planning that includes the channel sample and test hole data. This involves using the resource model as the base for the block morphology, a smaller parent block size, and a short radius estimation of the blocks using the production samples. The model process takes 5 hours to run each month and provides a tool to more efficiently and accurately project the monthly planned ounces.

3:45 pm

A Solution to a Common Problem in Ore Reserve Estimation

E. Isaaks; Earth Sciences, Isaaks & Co., Emerald Hills, CA

This paper focusses on a solution for ensuring the ore reserve model accurately predicts the tons and grade that will be available for mining at the time of mining. Generally, the estimates of an ore reserve model are poor predictors of future tons and grade due to “smoothing”. Attempts to control smoothing often include domain controls on sample selection and restrictions on the number of samples used to make an estimate. However, a preferred way of controlling smoothing is by judicious sample selection. This paper shows how local anisotropy kriging (LAK) reduces smoothing by selecting samples for each estimate which have values as close as possible to one another. This not only reduces smoothing, but also increases the accuracy of the estimates. All of this is accomplished without the use of domain boundaries even in significantly zoned deposits. Finally, a simple algorithm is provided which transforms the estimates of any reserve model to grade tonnage curves appropriate for the proposed degree of ore type selectivity at the time of mining.

TUESDAY, FEBRUARY 21

AFTERNOON

2:00 pm **Room 504**

Mining & Exploration: Management: Mine Cost Estimation and Economic Analysis II

Chair: *S. Stebbins, Aventurine Engineering, Inc.*

2:00 pm

Introduction

2:05 pm

Reducing Costs without Compromising Orebody Value - a Geologist’s Role during a Downturn

E. Ronald; Mining Geology HQ, Hillarys, WA, Australia

Geologists in exploration and production roles can greatly influence capital expenditure and C1 costs without compromising orebody value. During periods of industry downturn, geologists are commonly some of the first professionals to be retrenched. The repercussions of this short-term decision have long-lasting negative effects on both the company and the mining operation. This includes under-utilizing orebodies, lost revenue, and ultimately lost value for shareholders. Empowering geoscientists to think creatively, work smarter, and focus on economic measures means they can take a proactive approach in preserving or even improving orebody knowledge without increasing costs. Industry geologists must be the "voice of the orebody" by demonstrating and communicating the value of geological knowledge in optimizing mining operations. This will ultimately lift the profile of industry geologists and direct benefit the company's bottom-line.

2:25 pm 17-134

Building Services in Underground Mines – Significance from a Cost Estimators Perspective

T. Lupek[1], H. Mischo[1] and S. Plaum[2]; [1]Institute of Mining and Special Civil Engineering, TU Bergakademie Freiberg, Freiberg, Germany and [2]Department of Architecture and Civil Engineering, University of Applied Sciences Wiesbaden, Wiesbaden, Germany

The execution of classical building services in underground mining operations is more truth than myth. From small concrete foundations for conveyor belts to the construction of huge workshops for large machinery maintenance, nearly every operation requires building services. By creating such fixed facilities, these services ensure the efficiency of the production. A distinction must be made between fixed facilities which directly enable the production and auxiliary facilities which only indirectly support the production. The construction costs of such auxiliary facilities are often roughly estimated because they do not immediately contribute to mineral extraction. The research project 'Development of a systematic cost-calculation method for building services in underground mines' seeks to address the question: 'Can the construction costs concerning fixed auxiliary facilities be neglected e.g. within a prefeasibility study?' The presentation will show the monetary relevance and significance of these auxiliary facilities and introduce a guideline for cost estimators.

2:45 pm

Mine Development Project Risk Analysis

D. Berberick; Hecla, Coeur d'Alene, ID

Mine Development project risk is significantly different from ongoing operational risk. The primary reason for this is the unique facility delivered by a project which makes the use of historical performance less reliable for assessing risk. Project risk quantification requires determining the probability of cost and schedule variances, then assigning a percentage or a value as contingency for both cost and schedule. It is a formal process that includes engagement of the project stakeholders using Monte-Carlo techniques. The risk analysis is performed on the total project cost, excluding escalation and contingency. Cost elements for all project activities are evaluated for cost risk and an aggregate cost risk is established. The schedule risk analysis uses similar techniques and focuses on all project activities. The schedule logic is maintained during the risk analysis which allows cumulative effects of schedule risk for each project activity to be analyzed. Schedule and cost risk are two highly-linked processes and as such overall project risk can only be described by a composite risk analysis that looks at both cost and schedule risk.

3:05 pm

Simple Efficient Alternative to NI 43-101 and Other Codes

A. Ramcharan and N. Del Bel Belluz; Stantec, Mississauga, ON, Canada

Does the NI 43-101 or any other code really work? In a small global mining community, we should have one set of codes or guidelines. The aim will be to eventually propose a new set of guidelines that will be much easier to aid investors/reviewers and the general non-mining public in assessing a mining project and reduce scams. Mining investors are challenged by the various reporting standards worldwide, making it difficult to compare multiple international projects. Mining companies tend to prepare reports for investors based on the eventual stock exchange for which they want the listing. There are many resource/reserve codes worldwide that are considered acceptable for economic investments and market related reporting. These codes differ on exact subject; thus, mining investors don't have an international standard against which to benchmark projects. With today's technology, the world is moving towards a single market and therefore the mining industry should have one set of guidelines similar to the international environmental and social standards for project financing (Equator Principles). Generating specific global guidelines will help investors make prudent investments.

3:25 pm

Long Term Post Reclamation Closure Cost Esimates

K. Noyes[1] and S. Stebbins[2]; [1]CostMine, InfoMine USA Inc, Spokane Valley, WA and [2]Aventurine Engineering, Inc., Elk, WA

Costs associated with long-term project closure continue to elude pre-feasibility project evaluators. Tasks such as site monitoring, water treatment, sampling, and re-vegetation may all be necessary for many years after the site is reclaimed. Their costs must be considered in any pre-feasibility (and feasibility) level analysis. Unfortunately, the necessity, specifics, and duration of these tasks will not always be apparent during pre-feasibility. Details of a variety of potential long-term post reclamation tasks, and the process of estimating specific costs for these tasks, are discussed in this paper. Long-term closure costs suffer from an additional complication. When evaluators look into the economic viability of a proposed mining and mineral processing project, they often assume that the value of the source of their revenues (i.e., the recovered commodities) might escalate at a rate similar to the costs of producing those commodities. However, because the costs of long-term closure must be funded after revenue generation is complete, this assumption no longer applies. Because of this, methods of dealing with the possible escalation of closure costs over time are also discussed.

3:45 pm

Cost Estimates as a Design Tool - the Importance of Fully Interactive Modeling

S. Stebbins; Aventurine Engineering, Inc., Elk, WA

While an abundance of factors drive the design of mine, in the end the operation may simply not make a profit unless every factor that directly impacts costs is considered. Too often, the interaction of an unforeseen or unanticipated cost parameter with another undermines profitability after it is too late to remedy the oversight. The work presented here serves to describe mathematical approaches that can be used to incorporate all such parameters directly into the design of an underground mine, thereby providing a basis for the equipment and opening-size selection procedures that dictate project economics. This work details critical algorithms and suggests an approach that individual evaluators can use to set up their own spreadsheet-based models. While the data that defines them may not be readily apparent or available, most of the parameters required for this work can be reliably estimated. And, once the math is in place and the project modeled, an evaluator is provided an in-depth look into the balance between machine type, machine size, opening dimensions, and workforce needs. With the results in hand, adjustments can then be made to enhance economic viability.

4:05 pm

A Review of Real Option Models for Mining Resource Investment: an Era of Risk, Flexibility and Opportunity

K. Zhang; Energy and Mineral Engineering, Penn State University, University Park, PA

In the perspective of investment analysis, mining resource production retains critical features of risk management, flexibility strategy, accurate pricing and profit optimization. Since the introduction of the Black-Scholes' option pricing model in the 1970s, many efforts have been taken to analyze the mining investment issues incorporating all or some of these features. A number of vital contributions in this era, theoretically and empirically, have significantly improves the understanding of the real option value in mining activities. Several trends of the relevant literatures have been identified and compared interactively, for instance, 1) binomial tree/lattice method; 2) strategy based on simulation of stochastic process; 3) time to build issues in production; 4) optimized price threshold strategy and 5) empirical work. This paper presents a comprehensive overview of available literature on the application of real option theory on mining resources, and suggests possible directions of future research, and provides policy implications.

TUESDAY, FEBRUARY 21

AFTERNOON

2:00 pm **Room 502**

Mining & Exploration: Management: The Ancient Art of Sandbagging: Ensuring your Optimal Plan Is Achievable I

Chairs: *A. Brickey, South Dakota School of Mines and Technology, Rapid City, SD*
C. Roos, Montana Tech, Butte, MT

2:00 pm

Introductions

2:05 pm 17-054

Embrace the Unknown: Stop Saying "It's Too Hard" and Start Embracing Uncertainty in Your Mine Plans

C. Roos; Mining Engineering, Montana Tech, Butte, MT

Nearly every input to a mine plan is based on an estimate. The estimates may be from sample data, historical information, models, or personal opinion, but in all cases, these values are simply expected values (means). In real life, we don't get to iterate the exact conditions at our mining operation many times to ensure that that average value is attained. The expected value also tells us nothing about the spread of values that that input might take on. The result is a significant amount of unquantified uncertainty in our mine plans. Unfortunately, it is often too expensive or time consuming to update planning processes and software. This paper presents a proof of concept spreadsheet scheduling tool that can be utilized to incorporate many geologic realizations (simulated models) into the mine scheduling process and a low-cost Microsoft Excel based Monte Carlo Simulation of productivity and financial parameters. While this POC is not intended to be a detailed model of uncertainty, it is to show that there are stepping stones available for mine planners to begin to embrace uncertainty and produce more achievable plans without requiring a significant change in their planning process.

2:25 pm

OMP: a Project Scheduling Approach to Mine Planning

M. Goycoolea, E. Moreno and O. Rivera; Universidad Adolfo Ibáñez, Santiago, Peñalolén, Chile

Project scheduling, in broad terms, consists of scheduling activities over time, subject to sequencing constraints, to limited available resources, and various forms of uncertainty. When viewed this way, scheduling a mine plan, be it short term, long term, open pit, or underground, has a lot in common with scheduling any other major engineering project, including civil engineering, software development, and defense projects, among others. We describe OMP, short for Open Mine Planner. OMP is an academic modeling and optimization tool, comprised of algorithms found in the open academic literature, designed to model and solve a wide range of project scheduling problems. OMP combines integer programming and heuristics to compute provably optimal (or near optimal) solutions for large-scale problems. OMP has successfully been used for production scheduling of real mining operations, to incorporate complex modeling requirements in open pit, underground, and transition (open pit to underground) projects. In this talk we share some of the most important algorithmic techniques in OMP, present case studies, and compare OMP to commercial alternatives.

2:45 pm

Combining Optimization and Simulation to Generate Better Mine Plans

N. Morales, F. Orellana, J. Perez and H. Toro; Delphos Mine Planning Lab, DIMIN & AMTC, Universidad de Chile, Santiago, Chile

Optimization and simulation have been widely and successfully applied to mine planning. For example, optimization has been used for maximizing income, reducing costs, assisting the design of the mine, controlling financial risks; while simulation has been used to provide estimations of KPI's, evaluate the performance of some plans, or to improve mine operation models. However, as these examples indicate, these applications are separated from each other, with optimization in a more strategic scope and simulation being closer to the operation. This separation is good because corresponding models tend to focus on the best possible benefits of the techniques; however, it also has some drawbacks, as the resulting plans may not be completely realistic (in the case of optimization) or close to optimality (in the case of simulation). In this talk, we show some idea as to how optimization and simulation can be combined so the final results are more realistic and closer to an operatimal plan. We also present some real applications to problems in open-pit dispatch and underground construction and production.

3:05 pm

Effective Adaptation of the Mine Scheduling Workflow to Increase Implementation Certainty

J. Kraft, R. Diaz and M. Labonte; Minemax, Centennial, CO

Implementing a strategic mine plan at a detailed planning level is a core issue at many operating mine sites. Historical methods to overcome this issue rely heavily on individual capability and significant re-iteration and/or deviation at the receiving end. This can lead to an unhealthy, unsustainable environment for mine planners of both horizons and heightens the risk to losing strategic plan value during implementation. An approach to this problem is presented that focuses on adapting the strategic planning horizon with the aim to increase the certainty of accomplishing strategic goals when the result is translated to higher planning detail environments.

3:25 pm

Evaluation of HAULSIM as a Practical Tool in the Mine Planning Process

C. Gunderson[1], C. Roos[1], S. Rosenthal[1] and T. Bush[2]; [1]Mining Engineering, Montana Tech, Butte, MT and [2]Technical Services, Newmont Mining Corporation, Greenwood Village, CO

This project was intended to demonstrate the potential of in-house simulation software to validate a mine plan's robustness in replicating the actual mining environment. Many mining companies have built custom simulations for feasibility studies, however, most operating mine sites still rely on spreadsheets with average cycle times and productivity assumptions to estimate equipment requirements and productivity. Using HAULSIM, a software supplied by RungePincockMinarco (RPM), to simulate a mine's load and haul network, this project has demonstrated the practicality of using simulation at the mine site to certify that the current mine plan is achievable with the existing or planned equipment fleet. In-house simulation also provides the benefit of performing regular model reconciliation with new information after events to improve the robustness of the model and future value it can provide for the mine site.

3:45 pm

With Mines Going Deeper, Developing an All-Encompassing Passive Rfid Solution Can Help with Safety, Productivity, and Profitability

M. Brunet; K4 Integration Inc., Sales Manager, Sudbury, ON, Canada

Many newly discovered ore bodies have been found deep within existing mining infrastucture. Logistical costs to access and maintain these areas are high and any reduction in operating expenditures are crutial. Deploying a passive RFID in these circumtances or in new operations is benificial, as it can be used for: 1) Material handling and inventory: knowing what you have and where in the mine can make inventory management easy and reliable. Proactive ordering makes sure you never run out. Expensive equipment can be tracked in order to monitor its use. 2) Personnel tracking: energy used for lighting and ventilation can be controlled depending on activity in an area of the mine; dispatching is more efficient; safety accountability time during an emergency is reduced. Data from work habits can be stored and reviewed. 3) Ramp optimization is acheived by prioritizing its use depending on equipment. Newly developed tags are being introduced every day; these only add to the breadth where a passive RFID system can be beneficial. Tags can now be embedded in steel or hammered onto a skid, they can be carried by personnel without being intrusive, or they can be installed on vehicles.

TUESDAY, FEBRUARY 21

AFTERNOON

2:00 pm **Room 505**

Mining & Exploration: Operations: Practical Mine Ventilation

Chair: *J. Rahn, Newmont, Elko, NV*

2:00 pm

Introduction

2:05 pm

Underground Climatic Monitoring and Climatic Modeling: are We Missing Something?

P. Roghanchi[1], K. Kocsis[1], G. Danko[1] and A. Powell[2]; [1]Mining Engineering, University of Nevada, Reno, Reno, NV and [2]Barrick Turquoise Ridge JV, Ventilation Engieer, Winnemucca, NV

Selecting the most appropriate climatic monitoring system depends mainly on the purpose of climatic monitoring, the degree of the heat load to be removed, monitoring locations and costs. However, there are several complex events that cannot be captured when simple spot units are being used for climatic monitoring purposes. This includes the thermal damping effect, thermal flywheel effect, dynamic heat exchanges between ventilating air and surrounding environments, and unknown sharp increases in temperature during monitoring phases. This paper aims to discuss the importance of continuous climatic monitoring based on observation of the above-mentioned phenomena and highlight whether these cases have any impact on the overall climatic condition of an underground mine. The discussion will be based on over one year of climatic data collected at an underground mine in Nevada. Comparisons will be made between the in-situ data and calibrated ventilation and thermal models at the critical locations in the primary ventilation system. At the end, the importance of developing a dynamic ventilation-thermal-humidity model will be shown.

2:25 pm

Time-Dependent, Periodic Heat Flow and Temperature Model for Mine Ventilation

C. Lu, D. Bahrami and G. Danko; Mining Engineering, University of Nevada, Reno, Reno, NV

It is necessary to use the history effects in heat storage, known as the "thermal flywheel" in the rock strata around the shafts and drifts close to the intake of ventilating air. The thermal model of time-dependent temperature requires large size of data in vector as discretized function of the temperature variation with time. A known concept is used to reduce the size of history data by frequency decomposition of the periodic temperature function. Measured temperature data are used in the study. The temperature vector is decomposed into a range of frequencies expressed with the periodic cycle time of minute, hour, day, week, and month. Each frequency component is

characterized by the amplitude of the temperature signal, reducing the size of the sampled data vector into a single number. The wall heat flux vector as a response to the temperature variation at the strata interface is determined from the signal frequency and the amplitude using the heat conduction solution in the rock. The method is tested for accuracy and size reduction of the history data by numerical analysis through mine ventilation examples. Conclusions are drawn to evaluate the new solution method.

2:45 pm

Numerical Study on the Layouts of Auxiliary Ventilation Systems for Underground Mines

L. Wang[2] and S. Que[1]; [1]Mining, Missouri University of Science and Technology, Rolla, MO and [2]State Key Lab of Coal Mine Disaster Dynamics and Control, Chongqing, China

Optimized auxiliary ventilation design is crucial for an underground mining ventilation system. The main tasks of mine auxiliary ventilation systems are dilution of pollutants, mainly methane and CO, dust, and remove of heat from the blind headings of excavation or working faces. The most commonly used auxiliary ventilation systems are brattice line, auxiliary fan and ducting, and jet fan; each of them has at least two forms: exhausting and forcing. The auxiliary fan and ducting system has another form called overlap. In this study, the total of seven layouts of the auxiliary systems are investigate using CFD (computational fluid mechanism) tools. The numerical experiments are conducted in a 5 m by 5 m by 30 m blind gallery given the distances from the end of the system to the working face are 2 m, 5 m, and 10 m respectively. Four airflow speeds 1, 2, 5, 10 m/s are assigned to each scenario to examine the influence of air quantity. The turbulent mix, pollutant dilution, and heat remove effects are investigated and discussed.

3:05 pm

Lucky Friday Unit Ventilation System: Infrastructure Expansion and Improvement

M. McGee; Engineering, Hecla Limited - Lucky Friday Unit, Mullan, ID

Lucky Friday Mine is a deep, narrow vein silver mine in Mullan, ID. Its ventilation is a high pressure exhausting system. In 2015, a series of fan failures on the exhaust booster fans occurred. Lucky Friday reacted to the failure by employing a new booster fan arrangement and monitoring program which integrates the ventilation system into a state-of-the-art automation system installed with the #4 Shaft Project. This paper will discuss the cause and result of the exhaust booster fan failure, as well as how the program sets up Lucky Friday with a robust system allowing for operation at great depths.

3:25 pm

Improving Production Data Quality in Underground Operations

N. Ferreira; Marketing, Fleet Management, Modular Mining Systems, Tucson, AZ

One of the most prevalent challenges in underground mining is a lack of operational visibility. By implementing a fleet management system (FMS) designed for the underground environment, mines can know where their mobile equipment is, what it is doing, and how it is performing, at all times. Communication challenges underground make it difficult to capture reliable production metrics that can be used for effective decision making. An effective FMS addresses all major aspects of the development and production processes and provides a solution that manages the numerous ongoing sequential, concurrent, and parallel efforts, present in underground mining. With the right FMS, mines can realize increased equipment utilization and productivity, maximized material movement, reduced waste and operational costs, and enhanced operator safety. This presentation will demonstrate how an underground FMS helped an operation improve the quality of the production metrics through production cycle automation, offline data capture and automated communications network switching.

TUESDAY, FEBRUARY 21

AFTERNOON

2:00 pm **Room 501**

Mining & Exploration: Technology: Reaching the Mine's Full Potential: Technology Innovations in Underground Mining

Chairs: *P. Marshall, Barrick Hemlo*
V. Hui, Barrick

2:00 pm
Introduction

2:05 pm
The development of a 3D Virtual Mine Rehearsal Environment

G. Baiden[1] and C. Saunders[2]; [1]Penguin Automated Systems Inc., Naughton, ON, Canada and [2]Centre for Applied Neuroscience, Brisbane, QLD, Australia

Penguin Automated Systems Inc. and the Centre for Applied Neuroscience in Business have teamed up to combine Penguin's knowledge of mining and emulation gaming and neuroscience. Over the years Dr. Baiden has worked on many potentially game changing technologies. Some examples include a driverless truck that went into production in 1989 for 2 years moving all the mines material for that time until the ore was mined out; teleoperation of three LHDs for a central control room many kilometers from the mining site, the teleoperation of three production drills for a surface control that have been in operation for now 25 years amongst many others including a complete teleoperated mine. The question is why have these technologies now over many decades old have not been adopted? Neuroscience appears to have a very significant role to play in change management for our industry. The question is how to put the tools in place to support this change management. By Penguin, Dr. Baiden creating the 3D virtual Mine Rehearsal environment and Dr Saunders using his neuroscience capabilities we are working to solve this significant problem holding our industry back from achieving game changing results.

2:25 pm
Innovative Mine Management through Visualization
S. Goosney; Stantec, Tempe, AZ

In today's rapidly changing and competitive mining industry, companies must be attentive to all opportunities available to gain a competitive advantage. Using building information management (BIM) and visualization software packages as data gathering and communication tools, companies can leverage the latest technologies and procedures to coordinate and streamline exploration, production, refinement, and delivery of all goods and services. This paper will present how the effective use of 3D modeling and visualization tools can be leveraged in conjunction with current and emerging equipment and processes, including advanced digital technologies, to produce more productive and safe work environments, resulting in more profitable outcomes for all stakeholders. The presentation will illustrate the use of info graphics, animations, and interactive models in current workflows, what advantages are achieved by these, and how to move forward the collected data.

2:45 pm
Mine Underground Communications Infrastructure Guidelines
D. Fry; Global Mining Standards & Guidelines, CIM, Toronto, ON, Canada

The scope of the document set is to provide a planning and sustainability tool for mining personnel who are responsible to design, operate and maintain the communications systems and services used for safety and production purposes in an underground mine environment. Some of the advantages for using this document include: *Help non-IT personnel to better understand basic communications requirements during the planning, construction and production phases of the underground mine. *Provide a standard reference between mine staff, engineering consultants and solutions vendors when planning new underground mine communications systems or maintaining existing ones. *Help to identify the communications assets needed to support current and future mine technologies.

3:05 pm 17-138
Improving Modern Mining Methods for Moderately Inclined Tabular Deposits
T. Rockley[1], L. Rattmann[2] and J. Brune[1]; [1]Mining Engineering, Colorado School of Mines, Golden, CO and [2]THGA, Bochum, Germany

The mining of tabular deposits accounts for a significant portion of modern production in both underground hard rock and soft rock mining, but especially in the latter. There is a large discrepancy between the availability of tabular reserves and the amount of development of these deposits, particularly when the deposit has a dip of around 25-50 degrees. This project studied the technical and practical barriers to the mining of these deposits through modern and historical case studies. The primary technical barriers to the development of these deposits are material movement and roof support. The study of historical attempts overcome these barriers and why they failed allowed us to research implementing modern technology on previously unsuccessful methods, allowing for these methods to be reapplied successfully. If some common mining methods are slightly altered these deposits can be mined at only a marginal increase in cost and using readily available equipment. These modified methods could allow for previously underdeveloped deposits to become viable.

3:25 pm
Technology Innovation at Greens Creek Mine
B. Morgen; Hecla Mining, Juneau, AK

Greens Creek Mine is utilizing technology to continuously improve day to day operations. In the past 2 years Greens Creek has successfully implemented a full 3D planning and scheduling software system. This has helped highlight hazards and eliminate disconnects between long range and short range planning. The mine has designed and implemented multiple web based utilities for mine inspections and daily shift turnovers. Greens Creek has also installed a mine wide fiber optic / Wi-Fi system. This system has enabled Greens Creek to have more information readily available to mine supervisors and management. The fiber optic backbone has facilitated Greens Creek in moving forward with a centralized blasting system, equipment tracking, personnel tracking, VoIP communications, and increased airflow and gas monitoring. In the future Greens Creek is looking at automation and ventilation on demand as well as increased use of web based applications.

3:45 pm
Development of New Means of Pipeline Communication
N. Peter; Development Engineering, Saskatchewan Research Council, Saskatoon, SK, Canada

Over the years we have seen previously inaccessible deposits being successfully mined. Advanced technology is a key contributor to this success by providing a means to mine more efficiently at lower cost. Data communications plays a huge role in how successfully advanced technology can be utilized. Long distances, background noise and inaccessibility limits available options. In many cases, drill strings and pipelines can be used as a medium for a reliable, high speed two-way communication between ends utilizing acoustic and electromagnetic waves. Over the last 10 years Development Engineering of Saskatchewan Research Council has developed several methods for data communication and has demonstrated high bandwidth communications over long distances in mining environments. Applications for this technology are numerous, including drilling and jet boring. An overview of developed technologies will presented, including case studies and discussed.

4:00 PM
A Paradigm Shift: Developing, Refining and Delivering a Mobile Localization and 3D Scanning Technology for the Underground Mining Industry
A. Chapman; 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 scanning underground is an emerging field but so far has been constrained to conventional, stationary surveying set-ups. This presentation 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 sitewide positioning with precision comparable to surface L1 GPS, and as a necessity has evolved an impressive capability for mobile 3D 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.

4:15 pm 17-123

Underground Application of Ultra-Wideband Radio for Robust Positioning and Communication

C. Niestroj, S. Schade, G. Moellemann and K. Nienhaus; RWTH Aachen University, Aachen, Germany

Today Ultra-Wideband radio systems (UWB) have gained special significance for accurate positioning purposes. Its physical nature, using short wave pulses, allows for precise and robust positioning tasks especially in closed, narrow spaces such as underground mining environments, but also local machine positioning in open pit applications, facing dust, humidity and vibrations. At the same time robust, high data transfer rate can be achieved. Through smart combination by means of sensor fusion of the UWB with e.g. inertial navigation systems an even more precise positioning system is at hand. To achieve this task different filter options like Kalman and particle filtering can be employed. Also, the propagation of error regarding anchor positions and its influence on the precision needs to be analysed and evaluated especially with regard to the coverage area. This presentation will give an overview of the research activities and results in real world applications at the Institute for Mineral Resources Machine Technology of RWTH Aachen University. This covers especially the above mentioned fields for an integrated UWB positioning system in underground and surface mining applications.

TUESDAY, FEBRUARY 21

AFTERNOON

4:00 pm **Room 203**

Move Mining: Changing the Public's Perception of Mining

Move Mining: Changing the Public's Perception of Mining

R. Kilborn; The Kilborn Group LLC, Buena Vista, CO

Move Mining is a team competition open to students and professionals. The goal is to develop a positive message campaign to promote mining and the mining efforts worldwide. Help us share the positive message of mining and the global benefits of this crucial industry. Bring your dynamic concepts and your creative innovation. The top five teams will pitch their idea, live, to a panel of industry leaders and communication experts. The winners will receive a $5,000 cash prize and support from SME and sponsoring organizations during 2017 to help promote and package your winning concept. The winner will return in 2018 to the Annual Conference & Expo to share their campaign success and inspire others.

TUESDAY, FEBRUARY 21

AFTERNOON

2:00 pm **Room 707**

MPD: Industrial Minerals Flotation

Chairs: *T. Olson, Flsmidth, Midvale, Ut*
D. Nagaraj, Cytec Solvay Group, Stamford, Ct

2:00 pm

Introduction

2:05 pm

Rock Dust Surface Chemistry Modifications for Eliminating Cake Formation and Improving Dispersion in Coal Dust Explosion Mitigation Applications

Q. Huang; Minining Department, West Virginia University, Morgantown, WV

Rock dust is applied in underground coal mines to mitigate 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 112 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 Spectros¬copy (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 82.8% reduction in the dust explosion potential relative to untreated rock test applied by the wet technique.

2:25 pm

Optimized Amine Collectors for the Beneficiation of Phosphate

B. Makin and P. Dopico; Clariant Mining Solutions, The Woodlands, TX, Uganda

Phosphate deposits are beneficiated with the end goal of making phosphate fertilizers (i.e., MAP and DAP). While the flotation processes and reagents that are used differ from region to region, in most cases silica removal is a critical part of the process. Cationic collectors, such as amines, are often used to float silica particles. Using experience gained through the flotation of silica in the beneficiation of numerous minerals, Clariant has introduced an amine collector to the North American phosphate market that achieves the required grade and recovery targets at much lower dosages than the amines that are used today.

2:45 pm

Surface Chemistry Issues in the Reverse Flotation of Iron Ore

K. Shrimali and J. Miller; Metallurgical Engineering, University of Utah, Salt Lake City, UT

Reverse flotation of silica from hematite is by far the most common strategy for the processing of iron ore containing silica gangue. In reverse flotation, quartz, the major impurity in the iron ore, is floated using ether amines and iron oxide minerals are depressed using depressants such as starch. Analysis of wetting characteristics of hematite (Fe_2O_3) by contact angle, MDS, bubble attachment time and atomic force microscopy (AFM) force measurements show that the anhydrous hematite 001 surface is slightly hydrophobic at natural pH, in the absence of polysaccharides, with a contact angle of around 50^0. For alkaline pH, hydroxylation of the hematite surface occurs rapidly and the hematite becomes hydrophilic with a contact angle of 0^0. In this regard the role of polysaccharides in reverse flotation is considered since hematite is already hydrophilic at the alkaline pH where reverse flotation is usually carried out. Contact angle, AFM and flocculation experiments suggest that the role of polysaccharides is to restrict the adsorption of amine at the hematite surface, and that polysaccharides act both as a depressant and as a flocculant for fine hematite particles.

3:05 pm

Frother Evaluation for Improved Recovery and Selectivity in Column Flotation

X. Yang, Q. Huang and R. Honaker; Mining Engineering, University of Kentucky, Lexington, KY

A study was conducted to evaluate and compare the effectiveness of different frother types when used in a three-phase, continuously operating froth flotation system. The frothers included several carbinols and esters that are commonly used in industry as well as unique frother types. The three-phase tests were conducted in a laboratory flotation column utilizing a metallurgical coal as the feed material. The use of a flotation column neutralized the impact of water recovery and entrainment through the application of wash water and bias rate control. Physical properties of each frother were evaluated which found significant differences in surface tension and froth stability. The frothers were tested and compared on the basis of carrying capacity and separation performance as a function of volumetric and mass feed flow rates.

3:25 pm

Purification of Akselberg Calcite Ore by Cationic and Cationic-Anionic Reverse Flotation

P. Dhar, M. Thornhill and H. Kota; Department of Geology and Mineral Resources Engineering, Norwegian University of Science and Technology, Trondheim, Norway

The Akselberg calcite deposit in Norway is a high grade $CaCO_3$ ore with minor silicate and sulfide impurities such as quartz, pyrite, pyrrhotite, etc. Cationic (tallow 1,3-diaminopropane, Duomeen T) collector has been attempted in the purification of calcite by flotation with an aim of achieving calcite concentrate for its use in value-added paper industry. The feasibility of sulfides and silicates flotation from calcite by the above collectors has initially been judged from the Hallimond flotation, zeta-potential and FTIR studies on pure mineral systems and the results illustrate selective silicate and sulfide flotation from calcite at neutral pH region with both the collector systems. Further, selective flotation of silicate and sulfide impurities was tested in bench scale flotation with the Akselberg calcite ore and the results indeed showed that a calcite concentrate meeting the quality requirements for its use in paper industry for coating and filler purposes could be obtained. The major advantage of using this collector is to examine the usage of amines in place of toxic Xanthate collectors.

3:45 pm

Recycling the Fluorapatite from Secondary Sources Using Polymer-Assisted Flotation

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

The waste produced by the phosphate industry presents many challenges due to the economic and environmental impacts of their disposal. Simultaneously, scarcity of high-grade phosphate ores persuades researchers to find out novel methods to upgrade and recycle these secondary sources. Low P grade and high percentage of gangue minerals result in more difficult process to recover and higher cost to recycle. The goal of this investigation is to upgrade the phosphate content of the tailing produced by an elemental phosphorous production plant. Characterization studies such as SEM, EDS, XRD, mineral liberation analysis and electrophoretic measurements were firstly conducted to understand and identify the factors controlling the flotation performance. Laboratory experiments are carried out on direct fluorapatite flotation from gangue minerals using different dosage of collector, frother and depressant. Aluminum polyacrylamide is tested to distinguish its possible role in the flotation of fluorapatite and rejection of gangue minerals. The results represent that Al-PAM can be considered as a good assistant not only to improve the grades but also to reduce the consumption of other reagents.

4:05 pm 17-089

New Insights into the Role of Pb-BHA Complexes in Flotation of Tungsten Minerals

S. Han[1], Y. Hu[1], W. Sun[1], X. Li[2] and R. Liu[1]; [1]School of Mineral Processing and Bioengineering, Central South University, Changsha, Hunan, China and [2]Hu Nan Shizhuyuan Non-ferrous Metal Limited Liability Corporation, Chenzhou, China

Lead ions (lead nitrate) were introduced to modify the surface properties of tungsten minerals, effectively and selectively improving the flotability, with benzohydroxamic acid (BHA) serving as the collector. The experiments about the mode of addition and the ratio of lead ion to BHA indicated Pb-BHA complexes were the active species responsible for the flotation. The complexes generated by lead ions and BHA under different proportions presented different collecting abilities for different minerals. Thus the Pb-BHA complexes were designed for the separation of tungsten minerals from calcium minerals with little water glass. Hence a novel flotation process was developed for the recovery of tungsten minerals in Shizhuyuan Mine, China. Normal-temperature flotation of tungsten minerals was developed as an alternative to the classical Petrov process for scheelite-calcite-fluorite type ores. The disappearance, or decrease in, water glass content contributed to improving the recovery of tungsten minerals and the circulation of water and reagents.

4:25 pm

Flotation of Mushistonite from Low Grade Tin-Copper Gravity Tailings with Benzohydroxamic Acid

L. Sun, Y. Hu, W. Sun and M. Tian; School of Minerals Processing and Bio-engineering, Central South University, Changsha, Hunan, China

The beneficiation of mushistonite from low grade tin-copper gravity tailings in Tajikistan by flotation using benzohydroxamic acid (BHA) as a collector was studied. According to the tailings containing the mass of 0.49% Sn and 0.87% Cu, a concentrate containing the mass of 4.54% Sn and 12.13% Cu was obtained after only one rougher flotation stage, and the recovery of Sn and Cu were 57% and 61% respectively. Scanning electron microscopy with energy dispersive spectrum analysis and X-ray fluorescence analysis indicated the main tin and copper minerals were in the form of mushistonite, and main gangue minerals were carbonate, quartz and silicate. Flotation experiments in laboratory demonstrated that BHA was an effective collector to mushistonite activited by lead nitrate. Carboxymethylcellulose (CMC) and sodium fluorosilicate (SSF) used as depressants to gangue minerals were necessary. Pulp pH value, mixing time and temperature played significant roles in flotation of mushistonite. The optimum pH value of pulp was 6.5 to 7.5, the optimum mixing time was more than 30 minutes, and the optimum temperature was more than 20°C.

TUESDAY, FEBRUARY 21

AFTERNOON

2:00 pm **Room 601**

MPD: Plant Design II: Panel Discussion: Successful Project Execution: International Project Delivery Perspectives and Guidance

Chairs: *D. Meadows, Bechtel, Phoenix, AZ*
J. Arnold, Romarco Minerals Inc

2:00 pm

Introduction

2:05 pm

International Project Delivery

d. meadows; Mining and Metals, Bechtel, Phoenix, AZ

It's broadly accepted that mining projects are extremely demanding business undertakings and sadly, have a dismal record in returning shareholder value. Studies reveal that 86% of projects go over budget, 77% miss their start-up deadline, and 75% fail to meet quality or functionality specifications after becoming operational. But does it have to be that bad projects are so often the norm? Let's flip these figures around. Some 10 to 15% of projects actually meet all of their budgetary, schedule and operational goals. Experience from these minority winning projects, along with examination of the majority

SME TECHNICAL PROGRAM: TUESDAY

unsuccessful projects reveals that there are a set of known, fundamental principles that could completely turn our industry's record around!The International Project Delivery Panel Session will examine the project delivery process; and discuss specific actions for delivering a successful project. While the focus will be on best practices for development of large international projects, discussions should provide insight for execution of all sized projects within the mining industry.

TUESDAY, FEBRUARY 21

AFTERNOON

2:00 pm **Room 705**

MPD: SX-IX-EW

Chairs: *B. Varela, Freeport McMoRan, Tyrone, NM*
C. Cooper, Cytec, Tempe, AZ

2:00 pm
Introduction

2:05 pm
Solvent Extraction Auxiliary Tank Impeller Design Effect on Phase Separation Efficiency

K. Mallory[1], R. Kehn[2], A. Iniguez[3] and M. Filgueiras[4]; [1]Application Engineering, SPX FLOW, Inc., Rochester, NY; [2]Director of Mixing Research and Development, SPX FLOW, Inc., Rochester, NY; [3]Global Application Engineer, SPX FLOW, Inc., Rochester, NY and [4]Global Sales Director, SPX FLOW, Inc., Rochester, NY

Solvent Extraction in the mining industry uses mass transfer between aqueous and organic phases to recover target minerals, such as copper, nickel, or uranium, from a pregnant leach solution. The process starts with either heap leaching or slurry tank leaching. The target mineral is leached out and then sent to the Solvent Extraction System, where the mineral is extracted from the aqueous phase into an organic phase. The target metal is then extracted again into clean electrolyte solution and sent to the electrowinning plant to plate out the pure metal. The Solvent Extraction Primary Pump tank is required to achieve contact between the organic and aqueous phases for mass transfer. The Solvent Extraction Auxiliary tank is required to blend and maintain the dispersion formed in the Primary Pump tank for additional mass transfer. The Auxiliary tank agitator must provide gentle flow with little shear in order to reduce entrainment losses. This paper will cover four different agitator setups for the Auxiliary tank applications. Laboratory test results for each agitator design will be compared, which will include a phase separation time study and a cost comparison of each agitator design.

2:25 pm

Reduce Capital and Operating Costs for Solvent Extraction by Replacing Conventional Mixers and Settlers with Centrifuges

R. Finfrock and M. Baker; Resource Recovery Technologies, Tucson, AZ

Resource Recovery Technologies, LLC offers centrifugal solvent extraction (SX) plants using one bank of centrifuges for extracting copper and a smaller second bank of centrifuges for stripping copper. Both contacting and separating occur in each centrifuge. Process solution holdup in each centrifuge is approximately 652 gallons or 16,300 gallons in a typical 16,000-gpm centrifugal SX plant. This compares favorably to nearly 2 million gallons of process solutions (aqueous and organic) in a conventional mix-settler SX plant of equal capacity. This comparison of holdup volumes shows that an MSX centrifugal SX plant reduces holdup by up to 99% versus a conventional SX plant. Recent trials have shown that centrifuges can substantially reduce the amount of organic required to perform continuous solvent extraction. Additional benefits include significant reductions in evaporation losses, organic entrainment, and plant footprints, while significantly improving operator safety and environmental measures.

2:45 pm

Development of an on-Line Tool to Promote Optimal Electrowinning Performance

M. Moats[1] and C. Ward[2]; [1]Missouri S&T, Rolla, MO and [2]AMIRA International, Perth, WA, Australia

The mining industry is facing the retirement of technical experts and replacing them with process engineers with less than 10 years of experience. This has caused electrowinning facilities to re-invent solutions to problems already solved. To avoid these costly endeavors and promote optimal tankhouse performance, the AMIRA P705C project is developing an on-line troubleshooting guide or “expert system”. The guide provides operators with tools and information to assist them in rectifying non-conformances and save their operations significant costs in efficiency improvements and lower product quality downgrades.

3:05 pm

Solvent Extraction of Ammonium Peroxodisulfate Assisted Leach PLS Solution Using Response Surface Methodology

F. Dakubo; Univ. of Arizona, Tucson, AZ

Solvent extraction of copper pregnant solution (PLS) obtained from peroxodisulfate assisted leach was modeled using response surface methodology. Mixing speed, pH, reagent concentration and organic to aqueous (O/A) ratio were selected for testing. A pitched blade mixer was used in the experiment. The results indicate that, mixing speed, reagent concentration, pH and O/A ratio were all statistically significant to copper extraction. The response model developed has an R2 = 0.97 and Adeq precision of 28.3. A parallel kinetic comparing study using a straight blade Rushton turbine mixer showed no difference (p-value =0.308) between peroxodisulfate assisted leach PLS and conventional ferric and sulfuric acid leach PLS. Power draw and bubble size also showed no significant difference between both PLS solutions.

3:25 pm

Ionic liquids Deal with Rare Earth Elements: from Separation Technology to Advanced Materials

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

Rare earth elements (REEs) and their derivative products are critical materials in many frontline industries, such as clean energy, electronics, vehicles and transportation, aerospace and defense, healthcare, and chemicals. Various approaches have been employed for selective separation and processing of REEs. Ionic liquids (ILs) are not only considered as reagents for recovery of REEs but also have emerged as tunable liquid functional materials for a multitude of applications, and can be adjusted for specific needs in combination with REEs. The functionalizability of ILS makes them attractive for a range of applications such as catalysis, synthesis, separation, electrochemistry, materials science and medicinal chemistry. In this paper, current research trends and potential future directions in the design of IL-based technologies for separation of REEs, and functionalization of ILs by REEs for use in significant fields such as energy and advanced materials are discussed.

3:45 pm 17-088

Molybdenum Solvent Extraction using CYANEX® 600 Extractant

B. Gay[2], T. McCallum[1] and T. Bednarski[1]; [1]Cytec Solvay Group, Tempe, AZ and [2]Climax Molybdenum, Sahuarita, AZ

Molybdenum recovery by solvent extraction has gained interest partly due to advances in concentrate leach technology. In typical Mo SX flow sheets using amine-based extractants, rhenium recovery precedes primary molybdenum production due to the ability of the amine to co-extract Mo and Re. Alternatively, a phosphinic acid-based extractant (CYANEX® 600) can be used depending on the flow sheet. CYANEX® 600 selectively extracts Mo leaving Re in the raffinate, which is a valuable feature in plants which require rejection of the rhenium from the molybdenum circuit. CYANEX® 600 piloting results are reviewed including the operational cost savings generated by the different transfer mechanisms of the phosphinic acid-based extractant. The results are compared to commercial experiences with an amine-based extractant.

4:05 pm

Solvent Extraction of Praseodymium (III) and Terbium (III) from Mixed REEs Solution Using PC88A and Cyanex572 Extractant Diluted in Kerosene

V. Agarwal and M. Safarzadeh; Materials and Metallurgical Engineering, South Dakota School of Mines and Tech., Rapid City, SD

The solvent extraction of praseodymium (III) and terbium (III) from standard mixed solution of all rare earth elements (REEs) except promethium using 2-ethyl hexyl phosphonic acid mono-2-ethyl hexyl ester (PC88A) and Cyanex 572, has been investigated. The effects of aqueous equilibrium pH, various acid media (H_2SO_4, HCl, and HNO_3), extractant (PC88A and Cyanex 572) concentration, initial metal concentration and temperature on solvent extraction of both praseodymium (III) and terbium (III) were systematically studied. Based on the experimental results, HNO_3 and HCl were found to be the preferred aqueous media for solvent extraction of both Pr (III) and Tb (III). The most promising experimental conditions (pH, concentration of PC88A, metal ion concentration and temperature) were identified.

TUESDAY, FEBRUARY 21

AFTERNOON

2:00 pm **Room 506**

Professional Ethics Case Histories #1

Chair: *D. Abbott, Consulting Geologist LLC, Denver, CO*

2:00 pm

Professional Ethics Case Histories #1

D. Abbott; Behre Dolbear & Company, Denver, CO

This 2 hour session will be first in a series of presentations and webinars that will examine professional ethics case histories. While Mr. Abbott will present scenarios based on actual cases, participants are encouraged to contribute their thoughts on the ethical aspects of the scenarios presented and to contribute their experience with similar cases that may or may have reached the same ethical conclusion. The discussion will focus on both the case history as presented and how slight changes in relevant facts might lead to different ethical conclusions. The session builds on the "Fundamentals of Professional Ethics" webinar presented on November 3, 2016, which is available at http://www.smepromo.com/ethics2016. Participants may wish to bring a copy of the SME's Registered Member Code of Ethics with them for reference during the session, http://www.smenet.org/membership/join-or-renew/registered-membership and click on "Download the Code of Ethics."

WEDNESDAY, FEBRUARY 22

MORNING

9:00 am **Room 107**

Bulk Material Handling: Conveyor Maintenance and Safety

Sponsored by thyssenkrupp Industrial Solutions

Chair: *N. Madison, Cornerstone Conveyor Engineering*

9:00 am

Introduction

9:05 am 17-120

Speaking the Language of Accountants: Understanding the Payback of Safety and Justifing Expenditures for Safety Improvements

R. Swinderman[2] and A. Marti[1]; [1]Principal, RToddS Engineering LLC, Palm Coast, FL and [2]Princaipal, RToddS Engineering LLC, Palm Coast, FL

R Todd Swinderman, P.E., explains the benefits from improved conveyor safety as discussed in Martin Engineering's recent book FOUNDATIONS for Conveyor Safety: Perhaps more importantly, Swinderman presents a look at the accounting methodologies to use to show the payback on improved productivity and reduced accidents These standards and practices are designed to help the mangers of operations, safety, and maintenance show accountants and executives the payback that can result from improvements in safety. This presentation will highlight "return on safety" that investments in conveyor system systems and culture can provide. The presentation will showcase the methodologies he developed for and as discussed in Martin Engineering's forthcoming book FOUNDATIONS for Conveyor Safety

9:25 am

Safe Maintenance of Chutes and Equipment beneath Ore Passes and Bins

M. Peden; Stantec, Tempe, AZ

Maintenance beneath underground ore passes and surface bins has always required well planned and engineered bulkheads to ensure the safety of personnel undertaking the tasks associated with the work. In many cases, the installation of the safety bulkhead has proven to be a dangerous task in itself, exposing workers to unnecessary risks. A properly engineered system from the early design stages to final detailing provides for not only the imperative safety of maintenance personnel, but can also enhance maintenance productivity and reduce plant shut down schedule requirements. The following presentation outlines some common design techniques available to capture the safety and schedule benefits desired when undertaking the maintenance of chutes and equipment beneath a bin or underground ore pass system.

9:45 am

Abstract- Conveyor Improvements for Bulk Material Handling Safety by Design – Conveyor Upgrades

M. Bayley; ASGCO Complete Conveyor Solutions, Allentown, PA

This paper takes a fresh approach to safety, serviceability and lower Total Cost of Ownership, while continuing a proactive pursuit of minings high internal standards of safety and environmental stewardship. It is critical to use not only good housekeeping methods but also innovative and properly designed equipment. Continuous improvement and performance enhancement efforts require new technology to solve dust and spillage issues in bulk material handling conveyors. The topics addressed include dust and spillage control as well as maintenance and safety upgrades using new technologies. The paper looks at problems and solutions based on root cause analysis and life cycle costing. Specific topics include belt loading, belt cleaning, belt alignment and maintenance down time. Ease of access to eliminate confined space entry and ergonomics to promote a safer environment for workers is also part of the mining industry strong commitment to continuous improvement. Providing a safe workplace and meeting internal and global environmental stewardship goals are the cornerstones of commitment to its workers and the community.

10:05 am
Best Practices for Mechanical Drives on Heavy Duty Conveyors
C. Brown; Baldor-Dodge, Greenville, SC

Conveyors are complex systems which must provide continuous duty operation in challenging environments. The mechanical drive systems consist of gear reducers, belts and sheaves or a coupling, bearings and pulleys. These critical components work together to provide reliable, efficient operation. An issue with any one component can lead to system downtime. This session will discuss the best practices for selecting and maintaining a mechanical drive system. Topics will include selection considerations, installation, sealing options and lubrication.

WEDNESDAY, FEBRUARY 22
MORNING

9:00 am **Room 704**
Coal & Energy: CFD Modelling for Mine Ventilation

Chair: *K. Raj, University of Alaska Fairbanks, Fairbanks, AK*

9:00 am
Introduction

9:05 am
CFD Estimation of Fresh Air Requirements for DPM Dilution in a Metal Mine Stope
M. Khan, K. Homan and S. Gillies; Mining and Nuclear Engineering, Missouri S&T, Rolla, MO

Exposure to Diesel Particulate Matter (DPM) in underground (UG) metal and nonmetal (M/NM) mines is a serious health concern. Ventilation is a key component in controlling DPM and gaseous emissions from diesel engine exhaust. Especially at the work faces, providing adequate clean air is an important aspect of an UG mine ventilation program. In US M/NM mines, the required airflows are typically calculated by considering the particulate index and the specific nameplate ventilation rate. Overall mine airflow requirements are usually determined from total diesel engines power operating in the particular mine. Since required airflow in a mine is not individualized for a specific work stope, it can sometimes result in worker overexposure to mine air pollutants. The ventilation air required to provide desired conditions in a work stope depends upon many factors. This study uses 2D CFD to model a metal mine stope and determines the required air quantity based on specific diesel engine emission rates. Several scenarios were simulated. The findings from this study can be applicable to other M/NM mines since DPM and diesel engines characteristics are generally similar in different UG mines.

9:25 am 17-019
CFD Analysis on Gas Distribution for Different Scrubber Redirection Configurations in Slab Cut

Y. Zheng[1], J. Organiscak[1], L. Zhou[2], T. Beck[1] and J. Rider[1]; [1]Dust, Ventilation and Toxic Substances Branch, National Institute for Occupational Safety and Health, Pittsburgh, PA and [2]Fire and Explosions Branch, NIOSH, Pittsburgh, PA

The National Institute for Occupational Safety and Health (NIOSH), Pittsburgh Mining Research Division (PMRD) has recently developed a series of models utilizing CFD to study gas distribution around a continuous mining machine with various fan-powered flooded bed scrubber discharge configurations in an exhaust curtain working face. CFD models utilizing species transport model without reactions in FLUENT were constructed to evaluate the redirection of scrubber discharge toward the mining face rather than behind the return curtain. The study illustrates the gas distribution in the slab (second) cut. 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 models were validated based on experimental data and accurately predicted sulfur hexafluoride (SF_6) gas levels at four gas monitoring locations. One additional prediction model was simulated to consider a different scrubber discharge angle for the 100% redirected, equally divided case. This paper describes the validation of the models based on experimental data and the gas distribution results of the CFD models.

9:45 am 17-021
CFD Modeling of Longwall Tailgate Ventilation Condition

A. Juganda[1], J. Brune[1], G. Bogin[2], J. Grubb[1] and S. Lolon[1]; [1]Mining Engineering, Colorado School of Mines, Golden, CO and [2]Mechanical Engineering, Colorado School of Mines, Golden, CO

Ignitions of accumulated methane gas at longwall faces are well known to be some of the major causes of methane explosions in underground coal longwall mining operations. As a preventive measure, MSHA requires all underground coal operators in the United States to install methane monitoring devices on longwall shearing machines and at the tailgate end of the longwall face. Despite these effort, there are still regular occurrences of face ignitions. Some of these ignitions can lead to major mine explosions, such as the Upper Big Branch mine disaster in 2010, in which migrated methane from the gob to the shearer cutting drum where it was ignited, resulting in a major mine disaster. This methane had not been detected by any of the methane sensors installed near the longwall face. With the use of Computational Fluid Dynamics (CFD), a more detailed interaction between the intake air flow and various methane inflows at the longwall face can be modeled and visualized. The resulting airflow profiles will provide a better understanding of tailgate ventilation conditions that may lead to an accumulation of methane at the tailgate corner.

10:05 am 17-062
Evaluation of Gob Pressure Response Due to Changes in Mine Atmospheric Pressure

S. Lolon[1], J. Brune[1], G. Bogin[2], J. Grubb[1] and A. Juganda[1]; [1]Mining Engineering, Colorado School of Mines, Golden, CO and [2]Mechanical Engineering, Colorado School of Mines, Golden, CO

A longwall gob is mainly filled with broken rocks from the collapsed roof and becomes a porous medium where explosive methane-air mixtures can accumulate. In bleeder ventilation systems, this mixture can migrate out of the gob into the longwall face and other active areas in the mine during

barometric or ventilation-induced pressure changes. When external pressures change, the gob does not perceive this disturbance instantly but with a delay due to air flow resistance in the porous gob material. The delay of gob response to outside pressure changes increases the pressure differential across the gob and may cause an outflow of explosive air mixtures from the gob into the adjacent bleeder entries. With computational fluid dynamics (CFD) modeling, researchers at the Colorado School of Mines have evaluated the impact of gob pressure fluctuations on the outgassing of the explosive gas zones (EGZs), the magnitudes and rates of pressure changes, the volumes as well as the potentials location of outgassing if it occurs.

10:25 am

A New CED Model for Mine Ventilation

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

A Computational Energy Dynamics (CED) model is presented for the solution of large ventilation networks. The CED model incorporates the components of conventional CFD solvers including viscous/ turbulent dissipation and psychrometrics for evaporation and condensation. The model solves large mine ventilation networks in seconds with tens of thousands of branches, dozens of fans with performance curves, compression/expansion work, and large elevation and air density differences.The new element of the CED over a CFD model is the driving force of fluid motion: the mechanical energy in the CED instead of pressure in the CFD. The flow of heat in the CED is driven by the total thermodynamic potential lowered by the mechanical energy, as opposed to temperature difference in the CFD models. This provides superior converge in coupled flow and thermal models typical in deep and hot underground mines with natural convection. Application examples are presented using the new CED model which is integrated in the GUI of a conventional ventilation software. Test results are presented against Ventsim and VnetPC solutions as well as laboratory measurements in powered and natural ventilation problems.

10:45 am

The Effect of Environmental Factors on the Propagation of Methane Flames in the Longwall Gob

m. fig[1], G. Bogin[1], J. Brune[2] and J. Grubb[2]; [1]mechanical engineering, colorado school of mines, Littleton, CO and [2]Mining Engineering, Colorad School of Mine, Golden, CO, CO

Several recent mine explosions, such as the disaster at the Upper Big Branch mine in 2010 that caused 29 fatalities, have demonstrated that explosive gases can accumulate and ignite within and near longwall coal mine gobs. Prevention and mitigation of explosions of this kind require a fundamental understanding of flame propagation in enclosures and through rock features under varied environmental conditions. A combustion model was produced to examine the impact of water vapor concentration, temperature and surface wetting of simulated gob on the progress of CH_4 explosions. The CFD modeling of CH_4 combustion and flame propagation in humidified cylindrical vessels of various diameters with simulated gob is detailed, along with corresponding experimental results. The combustion model was developed in ANSYS for easy coupling to available ventilation models. Significant results include: 1) The CH_4 combustion model captures the effect of physical scale on explosions; 2) Humidity acts to retard the progress of the flame; 3) Water wetting on the simulated gob also acts to cool the flame and aids in quenching; and 4) increasing atmospheric and gob temperature increase burning velocity.

11:05 am 17-020
CFD Modeling of Pollutants Dispersion in Deep Open-Pit Mines under Arctic Air Inversion
K. Raj and S. Bandopadhyay; Mining Engineering, University of Alaska Fairbanks, Spokane, WA

Air inversion is a meteorological phenomenon generally occurs during winter times. Release of pollutants below the inversion height in an open-pit mine during periods of weak winds and consequently weak vertical mixing may result in very high concentrations of primary and secondary pollutants, causing serious consequences for health and safety of miners. Mine operations cease if the concentration of NO_x or CO exceeds the TLV of the pollutants. Artificial ventilation is required to dilute the pollutants to an extent that mine workers can safely resume work. Studies of the turbulence parameters suggest that effective ventilation of the pit and removal of pollutants can be accomplished if a large enough mixing length in the open pit can be created. Turbulent mixing by eddies of different length scales under an inversion layer is product of wind shear, thermal gradient and buoyancy. The main result of turbulence is mixing of the atmospheric profile and transport of momentum. CFD Simulation results of a novel mitigation approach using cloud cover will be presented in this paper.

WEDNESDAY, FEBRUARY 22
MORNING

9:00 am Room 711
Coal & Energy: Coal Preparation

Chairs: *T. Ghosh, University of Alaska Fairbanks, Fairbanks, AK*
A. Noble, West Virginia University, Morgantown, WV

9:00 am
Introduction

9:05 am
Mathematical Expansion of Coal Washability Data Using Constrained Splines
G. Luttrell[1] and A. Noble[2]; [1]Mining & Minerals Engineering, Virginia Tech, Blacksburg, VA and [2]Mining Engineering, West Virginia University, Morgantown, WV

Washability (float-sink) data are routinely used throughout the coal industry for plant design studies and performance evaluations. In nearly all cases, users of this data are forced to estimate values that fall between the endpoints of the specific gravity (SG) classes used in the float-sink tests. This interpolation is often performed using spline curves that are fit to the float SG versus cumulative mass and ash data. Unfortunately, these fits often result in back-calculated instantaneous ash values that are unrealistic since they violate the fundamental relationship between particle density and composition. To resolve this issue, a routine has been developed that uses an ash-constrained spline to

more accurately expand the numerical data. This article reviews the washability expansion problem and provides VBA code that can be copied into an Excel spreadsheet. The article also compares several sets of experimental washability data that have been expanded using unconstrained and constrained splines to illustrate the large calculation errors that can be avoided using this tool.

9:25 am

Retrofit of Deslime Stackcell Flotation at the Kanawha Eagle Preparation Plant

P. BETHELL[2], G. Luttrell[1] and M. Mankosa[3]; [1]Mining & Minerals Engineering, Virginia Tech, Blacksburg, VA; [2]Cardno, Inc., Bluefield, WV and [3]Eriez Manufacturing, Erie, PA

The StackCell technology is ideally suited for the treatment of by-zero coal feedstocks due to its compact size, high throughput and froth washing capability. The technology was recently installed in the Kanawha Eagle coal preparation plant to recover lost coal fines. Unfortunately, the installation struggled due to support equipment that could not handle the volumes of froth generated. Therefore, the flotation bank was redesigned as a deslime circuit in which slimes finer than 0.045 mm were discarded. This change (i) eliminated of the froth handling problem by lowering the frother concentration in the process water, (ii) increased coal recovery due to optimal frother dosing for the 0.15x0.045 mm feed, and (iii) improved moisture by discarding ultrafines. The redesign was challenging, however, since process streams within the fine coal circuit had to be rerouted to balance the volumetric flows demanded by the StackCell. This article describes the redesign of the Kanawha Eagle flotation circuit, reviews before and after performance data, and provides guidelines for future installations of the StackCell technology in deslime coal applications.

9:45 am

Particle Size Effect on Charge Distribution and the Impact on Triboelectric Separation Efficiency

j. chen and R. Honaker; Mining Engineering, University of Kentucky, Lexington, KY

Particle size is a key parameter determining the particle charging and electrostatic separation efficiency. The degree of liberation and total particle surface area both increase as the particle size is reduced which provides a higher likelihood of surface charge variants among the minerals due to differences in surface electronic properties. In this study, four particle size fractions of coal (+0.21 mm; 0.21-0.105 mm; 0.105-0.063 mm and -0.063 mm) were evaluated in a rotary triboelectrostatic separator to assess particle charge as a function of particle size. A modified Gaussian model was developed to describe the particle charge distribution which was used to identify the optimal particle charging conditions. Experiment results show that the particles having a size between 0.105 mm and 0.063 mm produced the highest quality clean coal with an ash content of 4.88% from a feed containing 26.31% ash when the particle charge distribution was the widest.

10:05 am

Beneficiation of High Ash Indian non-Coking Coals for Use in Power Stations

G. Thonangi[1], U. Chattopadhyay[3] and K. Sinha[2]; [1]Coal Preparation, Senior Principal Scientist, Dhanbad, Jharkhand, India; [2]Coal Preparation, Principal Scientist, Dhanbad, Jharkhand, India and [3]Coal Preparation, Principal Scientist, Dhanbad, Jharkhand, India

The Indian non-coking coal is of Gondwana origin, containing high ash wherein the extraneous material was intimately mixed in the coal matrix during the formation stage, causing high level of impurities in the run-of-mine material. The stipulation laid by the Government of India to transport coal of ash not exceeding 34% beyond 500 km with effective from 5th day of June'2016 will pose problems to different coal suppliers for the dispatch of coal to the power plants. The only solution to this problem appears to be the setting up of washeries to reduce the ash content. The paper highlights the possible beneficiation routes of washing high ash Indian non coking coals with detail characterization of clean coal for use in thermal power stations.

10:25 am

Assessment of Effective Removal of Fine Particles from Coal Washery Effluent Using Bio-coagulant

G. Kapse and S. SAMADDER; Department of Environmental Sc. & Engg., Indian School of Mines Dhanbad, Dhanbad, Jharkhand, India

The present study focuses on the use of Moringa oleifera pressed cake bio-coagulant (MOPCB) for the removal of fine particles from coal washery effluent. Moringa oleifera (MO) pressed cake/defatted cake (which is generally a waste material) after the extraction of oil (but containing active flocculation protein) was considered for the preparation of MOPCB. An attempt was made to investigate the relationship between the fine particle's characteristics and properties of MO pressed cake as a coagulant. Effluent samples were collected from the thickener outflow and investigated for physico-chemical parameters. Optimum operating parameters for maximum efficiency of turbidity removal, suspended solid removal and increased settling velocity were examined for varying dose of MOPCB. MOPCB as a coagulant achieved excellent reduction in turbidity (97.42 %) and suspended solid contents (97.78 %) at optimum dose of MOPCB of 0.8 ml/L (< 64 mg/L) with optimum contact time of 15 min and at 20 min of settling time at pH 8.5. As MO is considered as an environment friendly material therefore it may be recommended as an effective coagulant for treatment of the coal washery effluent.

10:45 am

Pico and Nano Bubbles and Coarser Bubbles Effects on Coal Ultrafine to Coase Size Particles Capturing in Column Flotation

F. Peng and Y. Xiong; Mining Engineering, West Virginia Universitiy, Morgantown, WV

Froth flotation with highly dispersed air bubbles techniques are used to recovery fine valuable matters from gauges. Flotation efficiency drops sharply with ultrafines and coarse particle size ranges. Our previous work showed that pico and nano bubble flotation can applied in recovery of wider particle size ranges in coal flotation, and reverse magnesium oxide flotation in phosphate ores. In this work, pico and nano bubbles are generated by packed column and cavitation venturi tube to improve collision-attachment, and reduce probability of ultrafines to coarser particles to enhance coal flotation performance. A 50 mm diam and 165 mm high flotation column was used to study the pico and nano bubbles affect the recovery of coal particles at various size ranges. For -700+325 μm coarser size range, recoveries are 27% to 16% higher, while -75 μm fine size range, 23% to 3% higher, at given product ash contents and recovery range from 60% to 90%, with pico and nano bubbles. Ppico and nano bubbles fill-up column and act like an additional hydrophobizing agent to increase flotation rate constant and effectively extended ultrafines to coarser coal flotation performance.

11:05 am 17-033
Deashing and Desulfurization of Fine Coal Using Enhanced Gravity Concentrator

Y. Tao; China University of Mining and Technology, Xuzhou, Jiangsu, China

Fine coal separation has been always concerned. The froth flotation is not efficient in desulfurization because of the low rate of sulfide liberation from raw coal, the natural hydrophobicity caused by sulfur concentration on the surface of sulfide, and the presence of large amounts of middling feed. An efficient centrifugal gravity separator was employed to separate for Shandong –0.5mm high sulphur coal, the partition curve of centrifugal separator was obtained with conclusion that the Ecart probable error value of the separator is 0.095, the imperfection I value is 0.128. Finally, comparing with the coal flotation using progressive release method, the result shows that the effect of the desulfurization with centrifugal gravity force field based on density difference between coal and minerals are much better than that of the floatation which operates based on the difference in surface properties. It provides a efficient technical way for fine coal separation.

WEDNESDAY, FEBRUARY 22

MORNING

9:00 am Room 702
Coal & Energy: Dust Control II

Chairs: *S. Schafrik, Virginia Tech, Blacksburg, VA*
G. Bylapudi, Southern Illinois University Carbondale, Carbondale, IL

9:00 am
Introduction

9:05 am 17-023
Characterization of Airborne Float Coal Dust Emitted During Continuous Mining, Longwall Mining and Belt Transport

M. Shahan, C. Seaman, T. Beck, J. Colinet and S. Mischler; Dust Control, Ventilation, & Toxic Substances, NIOSH - PMRD, Pittsburgh, PA

Float coal dust is produced by various mining processes and carried by ventilating air where it is then deposited on the floor, roof, and ribs of mine airways. If re-entrained in sufficient quantities, this float coal dust can propagate an explosion throughout mining entries. To assist the industry in further reducing this hazard, NIOSH's Pittsburgh Mining Research Division initiated a project to investigate methods and technologies to reduce float coal dust in underground coal mines through prevention, capture, and suppression prior to deposition. Field characterization studies were performed to determine quantitatively the sources, types, and amounts of dust produced during various coal mining processes. The operations chosen for study were a continuous miner section, a longwall section, and a coal handling facility. Respirable and total airborne float dust samples were collected and analyzed for each operation and the ratio of total float coal dust to respirable dust was calculated.

9:25 am 17-092
Open-Air Sprays for Capturing and Controlling Airborne Float Coal Dust on Longwall Faces

T. Beck, C. Seaman, M. Shahan and S. Mischler; NIOSH - Pittsburgh Mining Research Division, Pittsburgh, PA

Float dust deposits in coal mine return airways pose a risk in the event of a methane ignition. Controlling airborne dust prior to deposition in the return would make current rock dusting practices more effective and reduce risks of coal dust-fueled explosions. The goal of this NIOSH study is to determine the potential of open-air water sprays to reduce concentrations of total airborne coal dust (≤74 μm diameter) in longwall face airstreams. This study evaluated unconfined water sprays in a featureless tunnel ventilated by typical longwall face velocities. Experiments were conducted for two nozzle orientations and two water pressures for hollow cone, full cone, flat fan, air atomizing, and hydraulic atomizing spray nozzles. Gravimetric samples show that total airborne dust removal efficiencies averaged 19.6 percent for all sprays under all conditions. The results indicate that the preferred spray nozzle is operated at high fluid pressures to produce smaller droplets and move more air. These findings can be used to select sprays and design spray arrays to control total airborne dust over the entire longwall ventilated opening.

9:45 am 17-013
Assessing Foam Application to Mine Roof for Longwall Mining Shield Dust Control

W. Reed, Y. Zheng, S. Klima, M. Shahan and T. Beck; DCVTSB, NIOSH, Pittsburgh, PA

Underground coal longwall mining shield advance produces nearly 27% of the respirable coal mine dust during longwall mining. Foam application to the roof is a likely dust control for this source. Laboratory testing was conducted to determine the ability of foam application, at a simulated longwall shearer velocity, to a roof surface. Two foam generation methods were used; compressed air (CA) and blower air (BA). Using a new imaging technology, image processing and analysis using ImageJ produced quantifiable results of foam roof coverage. For CA foam in 650 fpm ventilation at 3 minutes (min.) after application, 98% of agent A was intact, while 95% of agent B was intact on the roof. At 30 min. after application 94% of agent A was intact while only 20% of agent B remained. For BA in 650 fpm ventilation, the results were dependent upon nozzle type. Three different nozzles were tested. At 30 min. after application 74-92% of foam agent A remained, while 3-50% of foam agent B remained. Agent A was the better performer for roof application. Roof application of foam is feasible establishing this technique's potential for longwall shield dust control.

10:05 am 17-136

After Market Coatings to Reduce Rock Dust Buildup on Underground Signs

J. Sismour, T. Resende, S. Schafrik and E. Sarver; Mining and Minerals Engineering, Virginia Tech, Blacksburg, VA

Signs in underground mines are subject to variable airflow, which carries dust and moisture. Often, dust buildup can reduce their visibility, hampering production efficiency and possibly safety. For instance, underground workers commonly must stop to clean signs in order to understand where they are in the mine or where critical supplies are located. There are currently a variety of coating products, including dust and water repellants, available on the market that have the potential to reduce dust accumulation on sign surfaces. This paper describes a preliminary study to determine their effectiveness. The study involved a practical testing protocol using a trickle rock duster and sample coupons cut from clean, used road signs. Product effectiveness was evaluated by comparing changes in sign luminosity after a period of rock dust application using image analysis software. By analyzing the frequency of different pixel luminosities on post-dusting sign coupons, both uniformity of dust coverage and the total amount of accumulation can be measured. Results indicate that at least one product may reduce the amount of dust buildup on sign surfaces.

10:25 am

Coal, Non-coal and Carbonate Mineral Mass Fractions in Personal and Area Respirable Dust Samples

K. Phillips, C. Keles, M. Scaggs, M. Rezaee and E. Sarver; Mining Engineering, VirginiaTech, Blacksburg, VA

Since about 2000, data collected under the Federal surveillance program to document Coal Workers' Pneumoconiosis (CWP) suggests an alarming rise in lung disease amongst miners in parts of Central Appalachia. While many factors may be at play, respirable dust and exposure characteristics, such as components, sources, and locations of exposure are clear focal points. As part of an ongoing study to comprehensively characterize dust, a thermogravimetric (TGA) method was developed to estimate the mass ratio of coal and non-coal minerals in respirable dust samples. The method also allows for discrimination between carbonate and non-carbonate minerals. This may be helpful in determining the amount of rock dust in the respirable size fraction, another issue of current concern. This paper reviews the TGA method and its verification, and presents results of nearly 200 personal and area dust samples gathered in eight mines across Appalachia. Results are analyzed with respect to mine region and operating characteristics (e.g., mining method, seam thickness), and worker occupation or sampling location in the mine.

10:45 am

Effects of Drilling Parameters on Respirable Dust Produced during Roof Bolting Operations

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

Analysis of the recent Mine Safety and Health Administration (MSHA) dust sample data shows that the number of excessive respirable dust exposure to roof bolter operators has increased significantly after the new dust standard of 1.5 mg/m^3 is applied. Our previous research works have demonstrated that properly controlled drilling to maintain a reasonably high bite depth (penetration per drill rotation) for the rock being drilled could significantly reduce the specific energy of drilling and improve the energy efficiency. The benefit

of using such concept to reduce noise exposure to the roof bolter operators has been proven. This research effort is to further explore the drilling control on the reduction of respirable dust generated during drilling process. Several laboratory drilling experiments have been conducted. Size distribution of the dust particles sampled from drilling with different bite depth has been analyzed. A rational drilling bite depth for a particular rock is to produce the least amount drilling dust in the respirable size range.

11:05 am

Laboratory Testing of a Full-Scale Physical Model of a Longwall Shearer for Investigating the Effectiveness of the Application of a Flooded-Bed Dust Scrubber on the Shearer

S. Arya, W. Wedding, A. Kumar and T. Novak; Mining Engineering, University of Kentucky, Lexington, KY

Dust control is one of the most difficult challenges for underground coal mine operators, especially longwall mine operators. Elevated concentrations of coal dust, particularly fine dust, are potential health and safety hazards. The most popular dust control technologies at a longwall face are ventilation air and water sprays, whereas a continuous miner face has the advantage of using flooded-bed scrubber along with ventilation air and water sprays. Previous research has shown significant dust reduction at continuous miner faces with the use of a flooded-bed scrubber on a continuous miner. In order to test the effectiveness of the integration of a flooded-bed system on a longwall shearer, the authors have fabricated a modified full-scale model of a Joy 7LS longwall shearer. The fabricated model has been installed in the experimental longwall gallery at the Pittsburgh Research Laboratory (PRL) of the NIOSH for testing. The aim is to improve longwall face dust control by embedding the flooded-bed dust scrubber on the shearer. The paper presents the results of the tests conducted at the PRL and the validation of the results through computational fluid dynamics (CFD) simulations.

WEDNESDAY, FEBRUARY 22

MORNING

9:00 am **Room 706**

Coal & Energy: Impacts of Climate Change Policies on Coal & Energy

Chairs: *H. Akbari, NC State University*
R. Mensah-Biney

9:00 am

Introduction

9:05 am

Climate Change and Coal Mining: the Hockey Stick and the Puck

G. Luxbacher; MELM Consulting, LLC, Prosper, TX

In January 2008, when the coal industry was on an upswing, President Obama gave a quip in an interview that forecast his intent for coal: “If somebody wants to build a coal-fired power plant, they can. It’s just that it will bankrupt them…" In March 2016 (and with the industry in depression), then-presidential candidate Hillary Clinton made the statement in a West Virginia town hall meeting "Because we're going to put a lot of coal miners and coal companies out of business, right?". Its easy to look at the policies of the Obama administration, often referred to by those in the industry as the "War on Coal", with its roots in climate change, and cast blame for the current and future plight of the US coal industry. Unfortunately, the coal industry finds itself impacted by a number of factors and decisions, some recent, others long-term, internal as well as external, that have led to the current conditions in addition to climate change. This presentation will examine these factors and decisions, including interrelationships, and discuss what this means for the future of coal mining and its coupling with policies tied to climate change.

9:25 am

Artic Sea Ice Then and Now – the Search for the Northwest Passage

B. Arnold; Preptech, Inc., Apollo, PA

Much concern has been raised about the diminishing Arctic Sea Ice in recent years. This should be a clear sign of global warming or climate change. However, looking back to purposeful voyages to find a Northwest Passage to the Orient, it is possible to find the adventures of wooden sailing ships that made historic reaches toward the North Pole and others that met with disaster. Articles from the Edinburgh Review in 1818 and 1853 give a unique perspective on Arctic Sea ice and other indications of the climate in Europe over many centuries. A review of these articles and some more recent information on global temperatures will be presented.

9:45 am

Impact of Coal Ash Disposal on Coal and Energy

H. Akbari and R. Mensah-Biney; NC State University, Asheville, NC

In 2015, coal was the energy source for about 33% of total electricity generated in the US. When coal is burnt in a power plant, two types of pollutions are left behind: first, the greenhouse gas emissions to the air such as CO_2 and N_2O, and second, the solid residuals known as coal combustion by products or coal ash. The climate change policies mainly addressing the air pollutions coming from coal have recently accelerated the slowdown in the coal industry. However, millions of tons of coal ash residuals disposed of in ponds and landfills across the nation have also had negative effects on the coal industry. The main purpose of this study was to analyze the current status of coal ash disposed in landfills and its effect on diverting from coal to natural gas as the energy source of electricity. A case study showing a series of events including the coal ash spill from a landfill to the adjacent river providing drinking water for downstream communities, changes in regulations regarding coal ash disposal and applications, and finally, switching the local power plants from coal to natural gas burning units in North Carolina is discussed in this paper.

10:05 am

The Role of Research in the Coal Mining Industry: Reflecting Back and Looking Ahead

J. Hirschi; Southern Illinois University, Carbondale, IL

The US coal industry has undergone some major transformations in the past half century. Each decade had its own issues varying from somewhat external concerns such as oil embargos and pollution control to very internal challenges such as the safety and productivity of the workforce. Through these transformations, the role of research has evolved from a proactive, industry-driven effort to a reactive, government-funded enterprise. The pros and cons of this evolution will be explored with an eye to the future and how research can best serve the industry.

10:25 am 17-004

A Study of Factors in US Coal Mine Closures since 1994

J. Brinkman, J. Schafler and C. Johnson; Mining and Nuclear Engineering, Missouri University of Science & Technology, Rolla, MO

The US coal mining industry has suffered a recent decline in profits caused by a combination commodity demand and government regulation, forcing coal mining companies to cease production in numerous mines. A 40% decrease in the total number of coal mines occurred from 1994 to 2000. The number of mines remained relatively constant until 2008 when a change of government sparked a series of new environmental regulations which have contributed to another 15% decrease from 2008 to 2016. In contrast, production has only decreased by 3%, increasing from 1994 to 2008, and then decreasing since 2008. However, this value is skewed by large increases in sub-bituminous coal production and decreases in other coal ranks. Several aspects assist in executive decisions on mine longevity and economic worth. Studies of open source mine data collected by mandated government surveys coupled with commodity history can be used to find relationships between mine closures and these elements, which include statistics on production tonnage, seam height, coal rank, etc. This paper looks at coal mining trends since 1994 by comparing mine, market, and regulation factors that may influence mine closure.

10:45 am

Sustainable Development of China Coal Industry in the 13Th Five Year Plan

B. Zhang; Derrick Corporation, Buffalo, NY

Global policy momentum is turning toward accelerating the inevitable transformation of global energy markets, where the renewables, storage and energy efficiency are favored over fossil fuels. The outlook for the global coal industry could be characterized as declining demand, excess supply, falling price, stock devaluation, under-utilized infrastructure, cost-cutting, excessive financial leverage, asset write-downs, unprecedented stranded assets and shareholder wealth destruction. The coal industry in China is undergoing a very tough period. China released its 13th Five Year Plan (FYP) which included its strategic objectives for the coal industry development. The study will discuss about those objectives and also steps the coal industry will take to achieve those objectives.

WEDNESDAY, FEBRUARY 22

MORNING

9:00 am **Room 104**

Coal & Energy: Research and Development I

Chairs: *M. Trevits, Xtraction Science and Technology, Inc, Pittsburgh, PA*
L. Ackah, Southern Illinois University at Carbondale, Carbondale, IL

9:00 am
Introduction

9:05 am **17-002**
A New Cast Hard Iron Elevated 250% the Service Life of Centrifugal Pumps in Multiple Wear Applications.

G. Calboreanu; A.R Wilfley & Sons, Longmont, CO

Hard cast irons are heterogeneous materials containing 1,600 HV hard chromium carbides embedded into a martensitic matrix. These are the most used alloys in wear resistant operations like mining, chemical industry, fracking, etc. The wear resistance of hard irons are increased in the following ways: - Reduce / eliminate harmful retained austenite and chromium + carbon depleted areas especially within eutectic cells. - Delay delamination between chromium carbides and matrix especially during sliding abrasion wear operations. Once the chromium carbide base is removed accelerated wear degradation occurs; - Evenly randomize and avoid discontinuities in the chromium carbide network. When chromium carbides are perpendicular to the wear surface wear rate is minimized. The new cast hard iron discussed in this paper fulfils and exceeds the above requirements increasing the casting service life around 250% and sometimes more in various wear operations. Physical and mechanical properties of Max5A are compared with well manufactured Industry Standard 25% Cr hard iron. The paper presents practical achievements in the USA, South America and India.

9:25 am
Variation in Time-Dependent Property of Rock and its Influence with Relaxation Test

Y. XUE and B. MISHRA; Mining Engineering, WVU, Morgantown, WV

Field observations have demonstrated that roof failure occur spatially in a mine from the time of excavation. It is suspected that time-dependent deformation propagates failure in the rock mass. In this paper, relaxation test was used to study the variation in time-dependent property and its influence on time-dependent roof failure was investigated by numerical simulation in 3DEC. The relaxation equation was developed from Burger's model. Variation in the time-dependent property in post-failure region showed negligible variation and therefore were averaged to represent the time-dependent property of failed rock. Finally, these parameters were used in the numerical simulation of underground excavations. Two groups of parameters were used to represent the time-dependent property for pre- and post-failure conditions. FISH functions within 3DEC were used to monitor the state of each zone and change the parameters to the values corresponding to failed rock once failure is detected.The results showed that this method accurately predicts the time-dependent propagation of plastic zone. The variation of the time-dependent parameters significantly affects the behavior of the rockmass.

9:45 am 17-049

Effective Application of Synthetic Aperture Radar Interferometry for Monitoring Mine Subsidence in the Mountain West United States

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

Differential Interferometric Synthetic Aperture Radar (DInSAR) is a satellite-based remote sensing technique capable of measuring centimeter level surface displacement with high spatial resolution over large areas. Regular monitoring of subsidence due to underground mine development is one potential application of DInSAR, and in this study, the application of DInSAR for subsidence monitoring is evaluated for two mining regions in the mountain west United States. In general, DInSAR has potential to identify the shape and extent of subsidence; in some cases, magnitudes and rates of subsidence can be defined. Importantly, the effectiveness of DInSAR for subsidence monitoring depends on the radar band (wavelength), the subsidence rate and the time between image acquisitions, and the topographic and vegetative surface characteristics.

10:05 am

Corrosion Studies of Roof Bolts Tested in an in-House Corrosion Test System with Simulated Underground Coal Mining Environment

G. Bylapudi, A. Spearing and K. Mondal; Mining and Mineral Resources Engineering, Southern Illinois University Carbondale, Carbondale, IL

Corrosion of steel roof support systems can be a serious threat to rock related safety and the effects can adversely impact the workforce safety. Stress corrosion cracking (SCC) is one of the roof support system failure mechanism that is encountered due to the combined action of stresses and corrosion medium. SCC of roof bolts in underground mining environment is considered to be a serious concern from the studies around the globe (references) and also from the authors' research. An in-house corrosion test system was designed and developed to test the full length roof bolts for analyzing the materials performance. To begin with, ASTM A615 grade 60 roof bolts were tested with and without stresses in a simulated underground coal mining environment for approximately 5 months. The mean strength results showed ≈13% strength loss for stressed bolts and ≈7% for non-stressed bolts from yield load data whilst from the peak load data the strength loss is ≈10% for both stressed and unstressed bolts. From these results, it can be concluded that this test protocol is applicable to test different roof bolts with desired modifications based on the respective underground mine environment.

10:25 am 17-061

Evaluating the Major Performance Characteristics of Current Standing Support Systems

T. Batchler; Engineer, South Park, PA

Longwall mines typically use some form of standing support for secondary roof support in longwall tailgate entries. Over the years, numerous secondary roof supports products have been developed for this application. Due to the multiple performance profiles, appropriate support selection and adequate support system design is critical to the prevention of ground falls and ground fall accidents. There are several major key areas that can determine the standing support performance characteristics, including initial support stiffness, peak load capacity and residual load characteristics. The purpose of this paper is to provide the mining community with a comprehensive assessment of mine roof supports. It evaluates the impact of various standing support application obtained through full-scale performance tests conducted using the National Institute for Occupational Safety and Health's Mine Roof Simulator. Through this program, tests were analyzed to identify correlations between the support design parameters and the resulting performance. The goal is to properly evaluate and verify that the roof supports are capable of proving adequate roof support for existing ground conditions.

10:45 am

Fractal and Pore Structure Analysis of Shengli Lignite During Drying Process

L. Feng; China University of Mining and Technology, Xuzhou, Jiangsu, China

Pore structure is one of the key factors that influence the dewatering, burning and conversion of lignite. In this study, the pore structure variation and fractal dimension of Shengli lignite in the drying process(150~500ºC) were investigated. The pore structure of lignite samples were obtained by N_2 adsorption/desorption at 77 K. And two fractal dimensions D_1 and D_2 were calculated using the Frenkel-Halsey-Hill(FHH) method at relative pressures of 0 to 0.5 and 0.5 to 0.95, respectively. The results show that the general pore structure varies slightly in the drying process. Mesopores are mainly the open cylindrical pores and cracks pores, and micropores are mainly one dead end pores. The variation trend of specific surface area is opposite to that of average pore diameter. And before the drying temperature reaches 300°C, the specific surface area, average pore diameter and mesopore volume show a "V" shape variation trend. The evolution mechanisms mainly included moisture evaporated, pore shrinkage and decomposition of functional groups. The changes in D_1 reflected the roughness of mesopore surface. The variation trend of D_2 indicated the volumetric roughness of micropore.

11:05 am

Effect of Coal Characterization on the Performance of Sedimentation Based Dewatering Equipments

S. KUMAR, S. Bhattacharya and N. Mandre; Fuel And Mineral Engineering, Indian School Of Mines Dhanbad, Dhanbad, Jharkhand, India

The present study includes characterization of coal tailing samples (-0.5 mm) collected from three Indian coal washeries and their effect on dewatering performance. A high molecular weight polymer was used as flocculant to improve flocculation and settling rate of coal fines. Studies show that the parameters such as ash content, particle size distribution, mineral matter, zeta potential significantly affects the flocculation and dewatering performance. A settling rate of about 190 mm/min was obtained for high ash coal samples. Coal with higher amount of fines (-63 μm) showed lower settling rates due to the higher surface area of solid particles. It was also obresved that, beyond certain flocculant dosage, the settling rate starts to decrease due to presence of insuffiencnt free particle surfaces for bridging contacts and steric effect of adsorbed layers. Zeta potential was found to be a significant parameters that affects the performance of sedimentation based solid liquid separation. The turbidity of supernatant liquid and the sludge density were also found to be affected with the change in the characterization.

WEDNESDAY, FEBRUARY 22

MORNING

9:00 am **Room 708**

Coal & Energy: Surface Mining: Advancement Through Innovation

Chairs: *J. Wientjes, Komatsu America Corp., Peoria, IL*
N. Rutter, Power Motive Corp.

9:00 am
Introduction

9:05 am 17-037

Determine the Potential Drill Utilization Improvements and Rock Fragmentation Requirements Using Directional Drilling in a Coal Mining Overburden Highwall Application

K. Dil[2] and S. Rosenthal[1]; [1]Mining Engineering, Montana Tech, Butte, MT and [2]Design Engineering, Atlas Copco Drilling Solutions, Garland, TX

This project analyzed the efficiency of incorporating the use of directional drilling technology into coal overburden blasting. Directional drilling is currently in use in the petroleum industry and it is believed that it will be a valuable asset in the mining industry. This project has shown that directional drilling can be a viable technology for use in the coal overburden removal process resulting in increased drill utilization and potential for cost savings. Future work regarding blasting and geotechnical evaluation should be performed to solidify the concept.

9:25 am 17-063

Evaluation & Selection of Novel Surveying Systems for Use in Surface Coal Mining

M. Drake[1], C. Roos[1], P. Conrad[1] and T. Stack[2]; [1]Mining Engineering, Montana Tech, Butte, MT and [2]Safety, Health and Industrial Hygiene, Montana Tech, Butte, MT

This paper presents the evaluation Montana Tech completed for the Western Energy Company Rosebud Mine relating to the benefits of survey data collected using novel technologies over traditional methods for topographic surveys. These technologies include Unmanned Aircraft Systems (UAS), photogrammetry, and laser scanning/LIDAR. Utilizing these technologies, large areas such as reclamation areas and cast blasts can be surveyed in a timely manner for use by the mining operation. The areas that were evaluated were the improvements in the safety of employees and the time required to collect data. In addition, there is also a potential cost savings for the operation, all while not affecting the accuracy of the data that is collected.

9:45 am

Westmoreland Coal Company - Maintenance Audit Program

J. Jutila, S. Fancey and J. Beard; Equipment Management, Westmoreland Coal Company, Billings, MT

The Maintenance Audit program was instituted as part of the Physical Asset Management (PAM) strategy. The basic tenet of the asset management strategy is to improve unit cost through improving equipment uptime and productivity and follows asset management practices that are globally accepted standards. The purpose of the audit is to: Assess each site's compliance to the maintenance strategy and identify areas of improvement; Identify Leading Practices and assess applicability at other operations; and Serve as the key tool for developing / improving the company-wide physical asset management strategy. The audit consists of: Maintenance Readiness Questionnaire; Tour of operations; Employee interviews – cross section of stakeholders in the asset management process including maintenance, operations, engineering, human resources, training, hourly, and staff; Attend management meetings; Review Relevant Documentation; and Assessment summary, opportunities, and a close out meeting. The audit is typically conducted by a small team of WCC maintenance professionals. Each audit is compared to prior audits to determine the rate of progression of each site in each of the audit sections.

10:05 am

The Value of Automation

S. Little; Suncor Energy, Calgary, AB, Canada

In recent years, it seems that all facets of the mining industry have been striving to achieve unprecedented performance improvement targets. The oil sands operations in Northern Alberta have not been exempt from these activities. Suncor is a leading producer in the oil sands and has been a pioneer regarding many aspects of oil sands development. A clear example of their latest technology advancement has been their commitment to the evaluation of the Komatsu Ltd. FrontRunner autonomous technology for off-highway mining trucks. This paper will discuss the key aspects of evaluating the feasibility of automation technology for the unique conditions present in the oil sands deposits. Time will be allocated to the steps used in the evaluation process, the key milestones achieved to date, and the potential benefits of autonomous mining trucks in the challenging mining applications of Northern Alberta. The attendee should obtain a general understanding of how a large mining operation has taken the initiative to pursue the first large-scale evaluation of autonomous truck technology in North America.

10:25 am 17-043

Dragline Extraction of 1.2 Million Tonnes of a 52-Meter Thick Vertically Dipping Coal Seam

T. Morris; SME, Edmonton, AB, Canada

From November 2014 through September 2016, Westmoreland's Coal Valley Mine utilized a Marion 7450 electric walking dragline to extract 1.2 million tonnes of a vertically-dipping, 52-meter wide, fault-thickened seam, beneath a conventionally-excavated pit bottom. Mine planning and operational hurdles encountered throughout a kilometer of mined strike length included mitigating highwall instability in both hanging and footwall slopes, water management, and end-of-life machine reliability and maintenance. The most substantial challenge has been the depressed global coal market. However, the successful application of this mining method significantly aided the overall cost of production at the site. The valuable experience gained from this project will be extended to future mining areas where this technique can be similarly applied.

10:45 am

Maximize the Data You Have

N. Priegnitz[1] and K. Krishnamoorthi[2]; [1]Komatsu America Corp. / Bradley University, Peoria, IL and [2]Industrial Engineering, Bradley University, Peoria, IL

Optimizing the efficiency and productivity of existing mobile equipment with minimal investment becomes a more important endeavor in slow market periods, and requires increased awareness of how equipment is being operated. Data collection systems, factory standard on most, if not all, mining equipment are one window on equipment performance; unfortunately, this data is frequently underutilized. This presentation will discuss and explore one application of common statistical techniques applied to haul truck payload data reported through standard Komatsu systems. These techniques are intended to help identify when an apparent change in reported data from one day to the next represents a fundamental change in the load-haul process, or is just reflective of natural variability. An attendee to this presentation should understand the general concepts behind, and potential applications for, this and related process control techniques.

WEDNESDAY, FEBRUARY 22

MORNING

9:00 am **Room 102**

Environmental: Surface Water Management: Life of Mine and Closure

Chairs: *L.Gonzales, Savci Environmental Technologies, LLC, Mesa, AZ*
D.Tucker, Arcadis US, Inc., Phoenix, AZ

9:00 am

Introduction

9:05 am 17-006

Aerial Drones Used to Sample Pit Lake Water Reduce Monitoring Costs and Improve Safety

D. Castendyk[1], B. Straight[1] and P. Filiatreault[2]; [1]Hatch, Lakewood, CO and [2]Hatch, Sudbury, ON, Canada

Aerial drones capable of collecting and retrieving water samples from pit lakes, tailings ponds and other mine-site basins will revolutionize environmental programs by cutting sampling costs and eliminating safety risks. Costs typically include a boat, boat transport, road maintenance, floatation devices, water-safety training and extra staff. Labor costs alone can exceed $20,000 US per sampling event. Hazards include potential for drowning, unstable pit walls and unconsolidated sediment surrounding tailings ponds. Hatch has developed a novel device for aerial drones which enables the collection of water samples from depths up to 150 m. This system only requires a pilot, a sample technician, and a safe operations point overlooking the water body. Hatch anticipates this will cut monitoring cost by at least 50% while improving safety, reducing staff and accelerating data acquisition. When paired with water testing equipment, we can perform site-wide surveys of multiple water bodies to generate a rapid assessment of water quality. This presentation will demonstrate the collection of water samples from a 100-m-deep pit lake, and will highlight the potential of this emerging technology.

9:25 am

Regulatory Requirements for Drainage and Sediment Ponds at Aggregate Mine Sites

P. Sullivan; Civil & Environmental Consultants, Inc., Pittsburgh, PA

A limestone producer in Appalachia operates an underground limestone quarry located approximately 500 ft. above a river. plant operations, including conveyors, crushers, stockpiles and an inactive railroad right-of-way are located on a plateau approximately 50-60 feet above the river. The company maintains a NPDES General Water Pollution Control Permit for the site which contains a subpart that includes compliance with an approved E&SC Plan. Stormwater collected from disturbed areas is routed through a series of hydraulic facilities before discharging into natural unforested drainage ways, which feed an unlined sediment pond on a narrow, natural bench. Infiltration is creating embankment instability, and the pond and discharge channel appear to be undersized for the permitted disturbed area. CEC prepared a design of three HDPE-lined forebay ponds and one HDPE-lined sediment pond to collect sediment and stormwater from disturbed areas, and used limestone screenings to construct the embankment. The value-engineered design utilized several unique hydraulic approaches to route stormwater down steep valley slopes. Construction was initiated in May of 2015 and completed in July of 2016.

9:45 am

Reduction of Risk with Automated Remote Monitoring

G. Heath[1] and M. Smith[2]; [1]Mining and Geological Engineering, University of Arizona, Tucson, AZ and [2]KGHM, Phoenix, AZ

Reduction of risk may be achieved with the application of an automated monitoring suite of sensors that consists of an integrated system that includes geophysical, hydrological radiological and a self calibrating chemical sensor network. There is a need by both government and private industry for long-term information on earth system behavior. The information needed for monitoring will vary from site to site but will include things like: water quality, areal distribution, ion specific contaminates temperature, bacterial types and quantities to name a few. The information need has operational, regulatory and scientific drivers. The integrated use of point source sensors with volumetric near surface geophysical methods when properly combined provide potential of providing highly detailed localized subsurface information on processes and subsurface behavior.

10:05 am

How Effective is Your Life-of-Mine Mine Water Management Program?

J. Lupo[1] and m. brunhart-Lupo[2]; [1]Newmont Mining Corporation, Greenwood Village, CO and [2]ReBel Consulting, Golden, CO

Mine water management is a critical component of any mine operation. Water is required in many areas of the mine ranging from ore processing (milling and heap leaching) to supporting mine reclamation work. However, as mining operations develop and expand, increasingly there is competition for the available water resources. This reality has resulted in focused efforts to minimize water consumption at all levels of a mine operation, with a Life-of-Mine (LoM) Water Management Plan (WMP) being central to that effort. A LoM WMP provides specific details how an operation manages its available water resources. Ideally, these plans are developed during the mine planning stage and continually updated throughout the mine life. While a LoM WMP can be powerful tool for managing water at a site, the effectiveness and application of the plan must evaluated and adjusted, as needed. Changes are constantly occurring at mine operations that affect water consumption and management. This paper discusses the important elements to designing, implementing, and monitoring an effective WMP. Pitfalls and challenges are discussed as well as opportunities to reduce water consumption.

10:25 am

Regulatory Drivers for Stormwater Management Improvements at the ASARCO Ray Mine

D. Yantorno; ASARCO LLC, Tucson, AZ

Stormwater discharges often present compliance challenges for mine environmental managers. The 7F Diversion Channel (also known as the F-Wash channel), is an innovative improvement to a 1970's-era earthen channel constructed to divert stormwater run-on around the ASARCO Ray Mine's Number 7 Rock Deposition Area (RDA). The storm flows in F-Wash drain to Mineral Creek, which is the principal watercourse through the Ray Mine and a designated "waters of the US". This paper will review the regulatory compliance drivers and their strong influence on the design and construction of the engineered solution to mitigate water quality impacts to Mineral Creek.

10:45 am

Design and Construction of Innovative Stormwater Conveyance at the ASARCO Ray Mine

D. Tucker; Arcadis US, Inc., Phoenix, AZ

The 7F Diversion Channel is a recent improvement to a 1970's-era earthen channel constructed to route stormwater run-on around the ASARCO Ray Mine's Number 7 rock stockpile. The storm flows in the channel drain to Mineral Creek, which is the principal watercourse through the Ray Mine and a designated "waters of the US". A fast-track value engineering and design-build approach with a partnering general contractor resulted in an innovative solution that enabled ASARCO to achieve a critical compliance deadline, while staying within their capital budget allowance. High design storm flows, complex topography, multiple contributing watersheds, and separation of contact and non-contact water along the 2-mile conveyance route were some of the technical challenges that needed to be overcome. This paper will review the design-build process and present the unique features of the constructed project.

11:05 am

Passive Treatment System for Mine Influenced Water Discharge from the Iron King/Copper Chief Mine

R. Buchanan; Environmental, Freeport McMoRan, Phoenix, AZ

A passive sulfate reducing bioreactor (SRBR) with an aerobic polishing cell was designed and installed at the Iron King/Copper Chief Mine (Iron King) south of Cottonwood, Arizona. This system was implemented under the auspices of Arizona's Voluntary Remediation Program (VRP) to passively treat mine influenced water (MIW) from two former underground copper mines. Construction was completed during one construction season in 2009, the system has been operating since that time and in 2016, is in OM&M mode. The SRBR cell was designed as a down-flow vertical reactor; with intermingled MIW input from two mine adits and conveyed by a subsurface pipeline to the SRBR. The SRBR was constructed in the shallow subsurface, with a light-weight fill cover consisting of a pumice overlain by wood chips, a geomembrane liner, and an upper hydro-seeded cap. The SRBR drains to a concrete-lined mixing pond which in turn feeds a multi-terraced aerobic polishing cell (APC), populated with native vegetation. Passively-treated MIW may be utilized for native vegetation irrigation.

WEDNESDAY, FEBRUARY 22

MORNING

9:00 am **Room 108**

Environmental: Sustainability and Remediation

Chairs: *K. Tonander, Souder, Miller & Associates*
N. Dent, Barr Engineering Co

9:00 am

Introduction

9:05 am

How the Mining Industry Can Save the Planet

J. Gusek; Sovereign Consulting Inc., Lakewood, CO

In the past 250 years, the mining industry has provided societies world-wide with the raw materials for a monumental industrial and technological revolution that is now coupled to global warming. This paper will present several easily-implementable programs of "closing the loop" in mining sustainability and carbon sequestration. Miners have created very big holes (VBHs) either using underground or surface mining techniques that are viewed as liabilities to mining companies or government entities that inherited them. Most VBHs are filled with mining influenced water (MIW) that is part of their lingering legacy. Fortunately, these MIW-filled VBHs are ideal for sequestering carbon in that they provide an ideal sink for backfilling with anything that will burn, even biosolids. Placing organic waste in landfills or incinerating it does not permanently sequester carbon as both processes yield greenhouse gases. Submergence of backstowed organic material in pit lakes or underground mine pools would sequester carbon as bicarbonate ion or elemental carbon. Over time, geochemically reducing conditions similar to those that created coal deposits would form; the carbon loop would be closed.

9:25 am

Field Investigation of in Situ Lime Neutralization of Acidic Sediment

J. Villinski; Clear Creek Associates, Tucson, AZ

Groundwater remediation using technologies such as pump-and-treat can lead to protracted remediation of aquifers impacted by acid mine drainage because solid phase reactions pose kinetic limitations on the release of stored acidity and metals to groundwater. Estimates of the time required remediate AMD-impacted aquifers can be many decades or longer. In situ alkali application is a potential alternative treatment technology to neutralize sediment acidity and sequester metals. A field-scale infiltration test was performed with a lime solution to evaluate the implementability of in situ neutralization of alluvial sediment impacted by AMD. Implementation issues included efficiently mixing solutions near solubility limits, controlling solids formed when mixing lime with makeup water containing bicarbonate alkalinity, delivering the lime solution to the impacted sediment without clogging the application facility or impacting the aquifer formation, and transporting the lime alkalinity throughout the treatment volume.

9:45 am

The Benefits of a Collaborative Design Build Approach to Completing the Investigation and Reclamation of a Legacy Mine Tailings Site

T. Morris; Barr Engineering, Jefferson City, MO

Reclaiming historic mine tailings sites can present unique design and construction challenges, particularly when sites are located in populated areas. Recently, reclamation activities were completed on a historic mine tailings site located in the middle of two towns. Prior to the start of reclamation activities, a portion of the site had been redeveloped into an industrial park, which included 15 commercial facilities. In addition, 54 residential properties and a city park had been developed immediately adjacent to the site. As a result, reclamation activities had to be completed to address complex geotechnical design issues, while taking into account the logistical challenges of working in a redeveloped area. Due to the challenging technical and logistical issues, a phased design and construction effort was implemented for the reclamation activities. This phased effort utilized a collaborative design build construction approach, which resulted in reclamation activities being completed in a manner that allowed construction to proceed without stopping, while maintaining the agreed upon schedule and causing minimal disturbance to the commercial and residential properties.

10:05 am

Reclamation of Iron Ore Scram Mining Tailings: Innovations in Establishing Native Vegetation

A. Kramer[1], J. Asp[1], N. White[1], J. Marinucci[1] and M. Lorenz[2]; [1]Short Elliott Hendrickson Inc., Virginia, MN and [2]Mining Resources, LLC., Chisholm, MN

Minnesota has robust reclamation standards with proven results in the taconite mining industry. New breakthroughs in scram mining technologies are producing fine and coarse tailings that have not been encountered nor reclaimed in Minnesota. Innovative research is underway to investigate and determine successful reclamation strategies to reclaim tailings from scram mining operations. Phase I: Bench scale testing to identify successful treatments to reclaim and restore scram tailings through evaluating "surface soil" amendments, viable seed mixes and plant germination, growth and densities. Phase II: Field scale pilot trial to test larger scale effectiveness of the treatments deemed successful in Phase I and test vegetative assemblages and planting techniques focused on the unique challenges with scram tailing basins. Phase III: Produce a technical report of results for the research, as well as compile prior reclamation results used previously in Minnesota iron mining reclamation projects on tailings basin applications. The presentation will step through the research proposal, Phase I bench scale results and subsequent Phase II design, implementation and year 1 field trial results.

10:25 am 17-105

Sustainable Green Technologies for Remediating Acid Mine Drainage and Impacted Soil

L. Ackah[1], R. Guru[1], M. Peiravi[1], S. Kumar[4], X. Ma[5], R. Ma[3], M. Mohanty[1], Q. Zhang[2], Y. Zhang[2] and B. Xing[2]; [1]Mining and Mineral Resources Engineering, Southern Illinois University at Carbondale, Carbondale, IL; [2]Department of Mineral Processing, Henan Polytechnic University, Jiaozuo, Henan, China; [3]School of Environmental Engineering, North China Institute of Science and Technology, Yanjiao, Hebei, China; [4]Civil and Environmental Engineering, Southern Illinois University at Carbondale, Carbondale, IL and [5]Civil Engineering, Texas A&M University, College Station, TX

Acid mine drainage (AMD) and acid sulfate soils cause surface water pollution through direct discharge, leaching and erosion. The study developed two sustainable and complementary green methods for passive treatment of AMD impacted water and soil. One method utilized the metal adsorbing and acid-neutralizing capacity of drinking water treatment residuals (WTRs) to treat AMD impacted water and soil. The other green approach applied the metal accumulating properties (phytoremediation) of two fast-growing, plants/grasses, such as Vetiver (Vetiviera zizanioides L.) and Pokeweed (Phytolacca americana L.) to clean metal-rich mine water and metal-contaminated soil. Batch adsorption tests, and lab-scale flow-through study of a designed fluidized filter column that employs WTRs as media significantly reduced the high iron, aluminum, manganese and sulfate concentrations in the influent acidic water collected from an abandoned coal mine site in Illinois. A greenhouse column leaching study was conducted with different rates of WTR amendment for pH control, metal immobilization and the complementary phytoextraction of the applied metal hyperaccumulators.

10:45 am

The Effect of Mineral Rights and Mining Activities on Municipal Waste Management in Mining Communities – Case Study in Tarkwa, Ghana

E. Kwesi[1], K. Awuah-Offei[2], R. Amankwah[3] and A. Duker[4]; [1]Mining/Geomatic Engineering, Missouri University of Science and Technology, Rolla, MO, USA and University of Mines and Technology, Ghana, Rolla, MO; [2]Mining and Nuclear Engineering, Missouri University of Science and Technology, Rolla, MO; [3]Mineral Engineering, University of Mines and Technology, Tarkwa, Ghana, Tarkwa, Western Region, Ghana and [4]Geomatic Engineering, Kwame Nkrumah University of Science and Technology, Kumasi, Ashanti Region, Ghana

An emerging effect of surface mining in developing economies is land scarcity for social and public services like housing and sanitation to support urbanization in mining communities. This paper examines the effect of mineral rights and mining activities on landfill site selection using the mining communities of Tarkwa, Ghana, as a case study. The paper analyzes

the relationship between mining and waste generation, the existing mining laws regarding land use, land ownership, and environmental responsibilities, and how these are affecting land acquisition for waste disposal. The authors observe that: (1) the presence of mining is a major factor contributing to increasing waste generation; (2) much of the land suitable for waste disposal are within mining concessions; and (3) mining companies exhibit "not in my back yard" stand towards landfill siting partly because the laws hold them responsible for environmental pollution within their concessions. The paper recommends that existing mining laws and policies should be reviewed to promote cooperation between mining and waste management agencies for landfill siting in communities surrounded by large mining concessions.

11:05 am

A Forward Looking Approach to Mine Closure and Remediation

J. Eldridge and T. Moyer; Black & Veatch, Kansas City, MO

Planning and implementation of successful mine closure necessitates that companies, communities and regulators assess the future land use of the mine while developing remediation strategies. Black & Veatch experience includes risk identification and mitigation, and understanding social-economic impacts to the local community. We use multi-disciplines within our company to integrate closure planning and implementation for a more sustainable environment acceptable to the stakeholders. It is critical to realize as early as possible that Acid Mine Drainage is one of the largest liability and management issue for closure. We provide effective solutions to minimize seepage through tailings/waste rock, assessments of erosion and slope stability, and reprocessing/recycling potential of low-grade waste materials as well as other essential assessments of surface water management. We specialize in developing long-term monitoring programs to evaluate the success of interim remedial actions and closure activities. This presentation will use examples from several mine sites to illustrate many of these critical issues associated with mine rehabilitation and closure.

WEDNESDAY, FEBRUARY 22

MORNING

9:00 am **Room 612**

Health & Safety: Applying Big Data to H&S

Chairs: *J. Gernand, Penn State University, University Park, PA*
A. Lashgari, Penn State University, University Park, PA

9:00 am

Introduction

9:05 am

Inferring the Economic Impact of Safety Incidents with a Random Forest Model

J. Gernand; Energy and Mineral Engineering, Penn State University, University Park, PA

Understanding the economic impact of mine safety incidents is one important piece of information to be used when making decisions on investment in equipment to mitigate hazards, changes in work rules, or regulatory policy. However, the infrequent nature of safety incidents and the lack of commonality between them can present so much uncertainty that decision makers may rely on optimistic assumptions for the effectiveness of hazard mitigations. Simultaneously examining many mines can provide such an answer. However, models often used to answer similar questions are based on linear regression and average out many of the important distinctions between worksites and individual incidents that they only find weak effects with any controllable factor. Random forest models are a "big data" tool with unique capabilities including their readability, their facility with incomplete data sets, as well as identifying conditional and threshold relationships that may be obscured by other methods. The results from these random forest models demonstrate how this economic impact varies under different conditions and offer possibilities to improve safety-related decision making.

9:25 am

Regressing into the Future; a Data Driven Predictive Approach to Safety

M. Savit; Husch Blackwell LLP, Denver, CO

Outside of the mining industry, data collected by the digital tools we use is accumulated and process to predict (with remarkable accuracy) future consumer behavior. Inside the industry, we collect remarkable amounts of data from the equipment and tools we use. That data is currently used, almost exclusively to either optimize equipment utilization or to avoid running components to failure (i.e. preditive maintenance). With very little effort, most, if not all of that data, can be tied to particular equipment operators and compiled to produce an operational portrait of that individual. Departures from that behavioral portrait can then be used to predict behavior which may presage unsafe acts or decisions. A limited database is already being used to predict fatigue among individual equipment operators with surprising accuracy. This paper will discuss the techniques that are currently being used for fatigue management, the results of that program, the sources of data that might be used to enhance the predictive power of that program and the potential for managing behavioral modifiers such as distraction or impairment.

9:45 am 17-116

The Constructive Role of Ventilation Models in Atmospheric Monitoring Signal Evaluation

W. Asante, D. Bahrami and G. Danko; Mining Engineering, University of Nevada, Reno, Reno, NV

It is prudent to interpret atmospheric monitoring signals in real-time for checking the safe limits of the air conditions in underground mines. In gassy mines, such real-time evaluation increases the safety of operation. In all mines, the continuous monitoring and evaluation contribute to maintaining air conditions to be within healthy and safe limits. Signal interpretation for safety conditions in mines is difficult for many reasons. An increase of hazardous contaminant concentrations can be predicted by signal pattern recognition, root-cause analysis of rapid changes toward deterioration and forward prediction in time using algorithms and numerical models. This paper focuses on analyzing signal patterns to recognize dangerous trends as well as forward predicting the various environmental and working conditions that may affect safety in underground mines. Efficient numerical ventilation model with heat and gas contaminant simulation components is needed for the analysis of real-time atmospheric monitoring data. Computational speed enhancement methods are discussed and tested in numerical examples, using the Jacobian sensitivity matrices for signal propagation prediction.

10:05 am

Roundtable Discussion: Looking Ahead to Applying Big Data Towards Improving Mine Health and Safety

A. Lashgari and J. Gernand; Energy and Mineral Engineering, Pennsylvania State University, University Park, PA

A round table discussion will be held at the end of this session to discuss the current state of infrastructure, research tools, and achievements related to mine health and safety and highlight areas of significant opportunity and continuing needs to apply big data driven research to this area. As part of this discussion, panelists will describe some of the main high value research questions that may be amenable to big-data-type research, as well as the current impediments in terms of data infrastructure and relevant tools that must be developed to address those questions. Recent achievements in this area will be put in context of the most important outstanding research needs.

10:25 am

Identifying High-Risk Health Exposure Groups Using K-Means and Hierarchical Cluster Analysis

R. Reed; Mine Safety and Health Program, University of Arizona, Tucson, AZ

Objective: Identify those groups with highest risk of overexposure to health hazards in the mining industry. Introduction: Preliminary analysis has demonstrated that exposures such as silver fumes, noise, diesel particulate matter, and respirable quartz, among others, as those health exposures with worst compliance. The states, job tasks, and mine locations associated with highest exposures have also been identified. Methods: With MSHA's publicly-available health sample and address/employment data, a relational database was created. K-Means and Hierarchical Cluster analysis will be performed with the R programming language. Cluster categories will include states, job tasks, mine locations, and commodity types. Anticipated Results: We anticipate identifying those characteristics associated with highest exposures and worst compliance.

WEDNESDAY, FEBRUARY 22

MORNING

9:00 am **Room 610**

Health & Safety: Research Informing Regulations and Compliance

Chairs: *E. Lutz, NIOSH, Spokane, WA*
M. Reiher

9:00 am

Introduction

9:05 am

Measuring Relationships Among MSHA Regulatory Actions and Injuries with Time Series (Vector Auto-Regressive) Techniques

R. Reed; Mine Safety and Health Program, University of Arizona, Tucson, AZ

Objective: To compare the relationships of MSHA regulatory actions with injury outcomes using vector auto-regression (VAR) in order to understand which may more effectively exert a preventative influence on injuries. Introduction: To date there is little empirical evidence to support or contradict the effectiveness of MSHA's activities. While some studies have produced evidence to support regulatory actions (Boden LI 1985, Johnson GR 1987), more recent studies have questioned their cost-effectiveness (Viscusi WK 1994, Kniesner TJ 2004). Methods: Data regarding violations & injuries from 2000-2015 were obtained from MSHA's publicly available datasets. Time series were divided into separate resolutions (monthly, weekly, & daily) & decomposed into stochastic processes. VAR models were created using multiple sets of lags. Model inputs included: citations, orders, sns citations, sns orders, inspection hours, & proposed penalties. Model outputs included: days lost, restricted activity, days lost & restricted activity, & no days lost or restricted activity injuries. Results: Some inputs, such as sns citations, demonstrate a significant, positively correlated relationship with injuries.

9:25 am

Does it Protect? The Role of Personal Protective Equipment in Mining

S. Moore, R. Stein, D. Chirdon and F. KilincBalci; National Personal Protective Technology Laboratory, NIOSH, PIttsburgh, PA

The National Personal Protective Technology Laboratory has published a draft National Framework for Personal Protective Equipment (PPE) - A Conformity Assessment Infrastructure to help ensure that PPE is safe for its intended use. The Framework consists of five steps: 1) identify hazard and define risk to workers; 2) identify PPE types needed to address hazards; 3) identify and select standards which address hazards and link to protection requirements; 4) based on the risk to the worker, define requirements and activities that will ensure PPE conform to standards; and 5) perform activities to assess conformity to specified standards. For PPE common to the mining industry—e.g., respirators, hard hats, protective clothing, hearing protection, kneepads, safety glasses, gloves, and boots—this paper will review pertinent PPE requirements and activities within the mining sector relative to this Framework. Additionally, this paper will discuss how mine operators, PPE manufacturers, and regulators may use this Framework to ensure that PPE being used by mine workers will provide the necessary protections.

9:45 am 17-009

An Evaluation of the Relative Safety of U.S. Mining Explosion-Protected Equipment Approval Requirements versus Those of International Standards

W. Calder[2], D. Snyder[1] and J. Burr[1]; [1]NIOSH, Pittsburgh, PA and [2]Calder Enterprises, The Villages, FL

"Explosion protection" refers to techniques used to minimize the potential for electrical and electronic equipment to create an ignition while operating in a hazardous location (HAZLOC). In particular, U.S. coal mines are required to use equipment in certain areas of the mine that has been approved by the Mine Safety and Health Administration (MSHA) for use in a methane and coal dust environment to limit the risk of the equipment creating an ignition-capable spark or a thermal energy ignition. In general, MSHA's regulations for explosion protection recognize two techniques: the use of explosion-proof enclosures (XP boxes) and 2-fault intrinsic safety for electrical and electronic equipment. Outside of U.S. underground mining, many industries and countries accept equipment that is designed to a consensus-based international standard (ANSI/ISA 60079-11 is the U.S. version for 2-fault intrinsic safety). The study presented in this paper provides an overall assessment of the ANSI/ISA 60079-11 standard and the MSHA ACRI2001 acceptance criteria, and determines if the ANSI/ISA document can be an alternative to ACRI2001 while maintaining an equivalent or better level of safety for miners.

10:05 am

Beyond Compliance: Innovative Monitoring Solutions for Respirable Dust and Crystalline Silica

J. Patts and E. Cauda; PMRD, NIOSH, Pittsburgh, PA

Worker's exposure to respirable dust and crystalline silica in the mining industry is a complicated occupational issue and can be affected by the type of mining, effectiveness of control technologies, and the spatial variability of the silica content in the dust. Monitoring the exposure in an effective way is paramount to protect the workers. Traditional monitoring approaches have known limitations such as the generation of a single data point for each sampling event. This can be overcome with the NIOSH wearable Helmet-CAM system which combines video and real-time respirable dust measurements and can pinpoint specific over-exposures and assess control technologies. The dust sample analyses cost and turn-around time are limitations of the traditional approach. NIOSH has been working on a new technique for silica quantification of collected samples on-site using portable infrared instruments. Silica samples have been collected from various metal/nonmetal mining operations to develop the calibration models and work is being performed on improving the analytical technique's response to confounding artifacts, as well as simplifying the hardware and software for various instruments.

WEDNESDAY, FEBRUARY 22

MORNING

9:00 am **Room 110**

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

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

9:00 am

Introduction

9:05 am

Microstructural Characteristics of Polymer-Induced Kaolinite Flocculation

S. Sharma, C. Lin and J. Miller; Metallurgical Engineering, University of Utah, Salt Lake City, UT

Despite their many uses, fine clay particles, such as kaolinite, present a problem in the management of tailings in various mineral industries such as the oil sands and phosphate processing industries. The effective flocculation, sedimentation and consolidation of these fine particles are major challenges. The structure of flocs and the water entrapped within the floc (intra-floc water) determine floc behavior and settling characteristics. Polymer (PAM)-induced flocculation of kaolinite has been studied with respect to size, shape and intra-floc water content for the first time by high resolution X-ray micro tomography (HRXMT). About 98% of the flocs were found to have water content in the range 30-80%. Size analysis revealed that about 90% of the flocs are less than 1.5 mm in size. In addition to analysis of individual flocs by HRXMT, flocs were analyzed for their microstructure by cryo-SEM. Visualization of primary kaolinite particles and PAM chains in the floc microstructure reveal stabilization of kaolinite microflocs in the web formed by polymer chains. The structure of the PAM polymer chains as well as the interaction between microflocs and the polymer chains is described.

9:25 am

Beneficiation of Industrial Minerals Using a Tribo-electric Belt Separator

P. Miranda; St Equipment and Technology, Butte, MT

Recently, ST Equipment & Technology, LLC (STET) has developed a processing system based on tribo-electrostatic separation. This dry technology provides the mineral processing industry a means to beneficiate fine materials. In contrast to other electrostatic separation processes that are typically limited to particles greater than 75μm in size, the triboelectric belt separator is ideally suited for separation of very fine (<1μm) to moderately coarse (300μm) particles with very high throughput. The high efficiency multi-stage separation through internal charging/recharging and recycle results in far superior separations that can be achieved with a conventional single-stage free-fall tribo-electrostatic separator. The triboelectric belt separator technology has been used to separate a wide range of materials including mixtures of glassy aluminosilicates/carbon, calcite/quartz, talc/magnesite, and barite/quartz. Separation results will be presented and economic comparison of using the tribo-electrostatic belt separation versus conventional flotation for barite/quartz separation will be evaluated.

9:45 am 17-108

Revisiting Scrubbing Unit Operations in the Phosphate Industry

F. Sotillo; PerUsa EnviroMet, Inc., Lakeland, FL

Scrubbing both horizontal and vertical are considered simple unit operations in the beneficiation of phosphate ores. In general, the operating conditions are fixed at high solids content based on the experience of the company responsible of designing this beneficiation step. Nevertheless, scrubbing is a complex unit operation designed to clean the surfaces of phosphate particles of slimes, break loose weak particles of impurities, and break clayish material. Therefore, it is considered that as high solids content as possible should be used to enhance particle-particle interactions (impact and rubbing) without taking into consideration the rheology of the system. However, scrubbing unit operations design requires studying the balance between the increase of particle-particle interactions with the cushion effect of slimes, clays and fines that decrease the availability of free water increasing the apparent viscosity of the phosphate slurry. This paper presents data from laboratory tests to determine the best operating conditions for the design of these unit operations based on the highest P_2O_5 grade obtained with the lowest impurities for different size fractions.

10:05 am

Retreating Oxide Tin at Lab Level – Gravity, Flotation to Generate Adequate Flowsheet

E. Blanco; FLSmidth, Herriman, UT

The processes of beneficiation and extractive have been reviewed of their main features and recent development. Also indicated is the need for development of processes to recover fine tin and tin from low-grade complex tailing ores. Coarse and fine Tin particle size interaction developments of separate stream and the process to build the best flowsheet design are in progress. Briefly shown are important tools like equipment features, mineralogy, and a scale from lab to industrial equipment. Results indicate additional recovery using hydoxamates to activate oxide Tin ore.

10:25 am

Recovery of Rare Earth Elements from Dilute Leachates Generated from Coal

A. Chandra[1], R. Honaker[1] and K. Han[2]; [1]Mining Engineering, University of Kentucky, Lexington, KY and [2]South Dakota School of Mines, Rapid City, SD

In light of the ever increasing worldwide demand of rare earth elements, there is a growing interest in exploration of viable alternative sources for the same. Efforts are underway at University of Kentucky to establish coal as a source of rare earth elements. This paper discusses the recovery of rare earth elements from the leachate solution by solvent extraction methodology using Di-(2-ethylhexyl) phosphoric acid. The elements were extracted in the organic phase using the D2EHPA and were subsequently stripped in the aqueous phase using sulfuric acid. The rare earth elements were then precipitated from the solution using oxalic acid. The rare earth element concentration was increased significantly by this process. An alternative methodology to recover the rare earth elements using organic ion-exchange beads was also evaluated.

10:45 am

A Microscopic Flow Model for Ultrafine-Particle Filtration

L. Pan[1], K. Huang[2] and R. Yoon[2]; [1]Chemical Engineering, Michigan Technological University, Houghton, MI and [2]Mining and Minerals, Virginia Tech, Blacksburg, VA

Darcy's law has been used extensively to model cake filtration. It is a macroscopic model, in which particle size dominates the filtration kinetics and cake moisture. In the present work, a filtration model based on flow through mono-sized capillaries has been developed. The new model differentiates from the Darcy's equation by incorporating the microscopic parameters such as capillary radius and disjoining pressure, which may be important for dewatering ultrafine particles. Laboratory-scale pressure filtration tests were conducted with 2 um top size east Georgia kaolinite clay. The results show that dewatering kinetics is strongly dependent on capillary radius, which in turn is influenced by surface hydrophobicity and charge. The model parameters determined experimentally show that use of a hydrophobizing reagent can greatly improve fine particle filtration due to hydrophobic coagulation. It has been found that the kinetics of dewatering kaolin clay is fastest at a pH where the layer-structured particles coagulate with a face-to-edge orientation. The capillary flow model developed in the present work may be useful for designing filters and optimizing operating conditions.

WEDNESDAY, FEBRUARY 22

MORNING

9:00 am **Room 112**

Industrial Minerals & Aggregates: Innovations in Industrial Minerals

Chair: *B. Li, Michigan Technological University, Houghton, MI*

9:00 am

Introduction

9:05 am

Recycling Industrial Minerals: a Not So "Secondary" Raw Material Source

M. O'Driscoll; IMFORMED Industrial Mineral Forums & Research Ltd, Leatherhead, UK

The strive towards a circular economy has boosted the evolution of recycling industrial waste. In turn, this has increased the potential of recycling industrial minerals from certain waste streams as technical and economic challenges in their sourcing, processing, and distribution are overcome. Recycled industrial minerals will soon be a standard option on the mineral consumer's menu, competing with primary raw material sources on cost, quality, and availability. A new supply chain of recycled industrial minerals is evolving to meet both market demand and our environmental expectations. This paper reviews some of these new industrial mineral sources, their markets, and the challenges in their development and acceptance.

9:25 am

Discriminating Cristobalite and Tridymite States in Diatomaceous Earths and Refractory Matrices Using Thermal-XRD and TGA-DSC

G. Tomaino; Minerals Technologies Inc, Easton, PA

Present regulations consider crystalline silica (quartz, cristobalite, tridymite) as “known human carcinogens”. Previous talks at SME sessions centered on discriminating opaline states (opal-A, opal-CT, opal-C) and opaline states versus cristobalite or tridymite within clay matrices. This talk is an extension of these previous presentations concentrating on the delineation and determination of cristobalite or tridymite phases within diatomaceous earths (flux-calcined and in-situ fluxed calcined) and refractory matrices. To confirm a crystalline state of cristobalite or tridymite versus opaline states a combination of known NIST reference materials (1878a quartz and/or 1879a cristobalite) can be used as internal standards to observe alpha to beta and beta to alpha transition states using Thermal-XRD and TGA-DSC.

9:45 am

Mullitization of Andalusite and its Effect to Ceramic Sinterability: Microstructural Indications

B. Li[1], M. He[2] and H. Wang[1]; [1]Michigan Technological University, Houghton, MI and [2]Research Center, Wuhan Iron and Steel Corp. Group, Wuhan, China

Andalusite is a silicate mineral containing high alumina. It has been used as raw materials for refractory ceramics due to its mullitization at high temperature. However, the phase transformation from andalusite to mullite is not only the re-allocation of chemical components but the re-organization of microstructure, which plays a critical role for the effective applications of andulusite. This study investigated the microstructural characteristics during the phase transformation from andalusite to mullite and its effect to ceramic sinterability. The results showed that newly born mullite appeared as rod-like or acicular microcrystals and dispersed around the initial andalusite. At 1150°C, the mullitization of andalusite was started, but the completely mullitization was found until fired at 1450°C. The compressive strength of the ceramics increased from 93.7 to 294.6 MPa while increasing the fire temperature from 1150°C to 1450°C. The appearances and distribution of mullite crystals are critical to the mechanical properties of the ceramics. The smaller the particle size of initial andalusite, the stronger of the ceramics.

10:05 am 17-097

Pre-Concentration by Automatic Sorting

C. Petter[1], A. Young[1], M. Veras[2], A. Bastos Neto[1], R. Paranhos[3], E. Gomes[3] and C. Sampaio[1]; [1]UFRGS, Porto Alegre, Brazil; [2]Tecnologia Mineral, IFAP, Macapá, Amapá, Brazil and [3]UNIPAMPA, Caçapava do Sul, Brazil

The major challenges of the current mining are the energetic optimization, the lowest water consumption and minimizing environmental impact. One technique that eliminates much of the waste avoiding milling sterile, operating without water and to decrease the generation of waste at the end of the process, must be considered a major innovation. One of the most important developments in these past 10 years in the mining industry was expanding the use of high-tech sensors aimed at pre-concentration of ore. Among the mining areas where this type of technology is booming is the industrial minerals. The most common sensors are color sensors with Charge – Coupled Devices (CCD cameras) allowing through the RGB colorimetric system, the separation of minerals with different hues, and in many cases, a difference in brightness. More recently, the development of the use of dual energy X-ray transmission (DE-XRT) Dual Zone allowed the separation by atomic density of the mineral constituents of the rock. This paper presents a review of these two techniques (CCD and DE – XRT) as well some results showing the use of these two technics for Earth Rare and Limestone.

10:25 am

Impact of Cementation on Hydraulic Fracturing Sand Viability

K. Anderson; Kraemer Mining & Materials Inc, Burnsville, MN

The degree and type of cement in sandstone play an important role in determining the viability of a deposit for hydraulic fracturing sand. While loosely cemented sandstones represent the best deposits, other sandstones that are more cemented are sometimes advantaged due to location and or grain size characteristics. Degree of cementing typically can vary throughout deposits causing possible variability in quality. Both the type and degree of development of the cement should be assessed in sandstone deposits. Various techniques to determine and assess hydraulic fracturing sand viability due to degree of cementation will be evaluated from the presenters experience with the operation and/or development of 6 sandstone mines and numerous exploration and drilling projects throughout the US.

10:45 am

A New Chemical Scheme for the Flotation of Rutile from Garnet

S. Song; Wuhan University of Technology, Wuhan, Hubei, China

The common collectors for rutile flotation, such as salicylic hydroxamic acid (SHA) and styrene phosphoric acid (SPA) are featured by their high selectivity and poor collecting. In this work, a new chemical scheme, which used Pb^{2+}as activator and emulsified kerosene as intensifier, has been developed for the flotation of rutile from garnet. The study was performed on the single minerals of rutile and garnet by micro-flotation and the measurements of zeta potential, adsorption capacity and XPS. Also, the scheme was tested on the artificial mixed minerals. The experimental results have shown that lead ion could greatly improve the flotability of rutile with SHA as the collector, but not garnet. It was attributed to the adsorption of Pb^{2+} on rutile in the form of $Pb(OH)^+$ complex interacted with the Ti-OH on rutile surfaces, forming surface complex $Ti\text{-}O\text{-}Pb^+$. In addition, it was found that emulsified kerosene could significantly improve the flotability of rutile with SHA or SPA as the collector, while garnet did not float. With this scheme, high separation efficiency of rutile from garnet was achieved by flotation. Also, the new scheme functioned well at a low slurry temperature.

11:05 am
Phyllosilicate Nanoparticles for Li-Ion Batteries

Y. Lin[1], X. Wang[1], J. Liu[2] and J. Miller[1]; [1]Metallurgical Engineering, University of Utah, Salt Lake City, UT and [2]School of Metallurgy and Environment, Central South University, Changsha, Hunan, China

Li-ion battery technology has been applied for both flexible portable electronic devices and more recently for transportation systems including hybrid and fully electric vehicles. These markets present different challenges in battery cell design, the former requiring generally higher power density, and the latter requiring higher energy density for increased travel distances. The need for better technical performance with improved conductivity and diffusivity is well documented. A novel nanocomposite organic/inorganic material using certain phyllosilicate nanoparticles has been identified as a potential solid polymer electrolyte system that can exhibit high Li-ion conductivity at room temperature. This nanocomposite PEO-based electrolyte can be used for high energy solid-state Li-ion batteries over a wide range of temperatures. The use of such a thin membrane electrolyte will simplify solid state design, lighten packaging and improve safety. Li-ion batteries with this new solid nanocomposite electrolyte having phyllosilicate nanoparticles can be used for energy storage, electric vehicles, portable electronic devices, and micro-scale batteries for sensors.

WEDNESDAY, FEBRUARY 22

MORNING

9:00 am **Room 501**

Mining & Exploration: Management: The Ancient Art of Sandbagging: Ensuring Your Optimal Plan is Achievable II

Chairs: *C. Roos, Montana Tech, Butte, MT*
A. Brickey, South Dakota School of Mines and Technology, Rapid City, SD

9:00 am
Introductions

9:05 am
Efficient Generation of Open Pit Precedences for Scheduling and Optimization

M. Deutsch; Maptek, Lakewood, CO

Open pit mine scheduling and optimization relies on first establishing precedence relationships between all of the blocks in the geologic model. Precedences must be constructed so that they balance flexibility, geometric accuracy, and computational efficiency. Common precedence schemes, such as 1:5:9, do not correctly account for slope accuracy in the off axis directions or at a large scale. In this paper a computationally efficient, flexible, and accurate scheme for generating, storing, and using precedence arcs is introduced. This scheme defines the precedence graph with fewer 'arc templates' and does not require the entire graph to be stored at any one time which translates to significant savings in both memory usage and computation time. This is flexible with respect to arbitrary domains, and varying slope angles and is also designed to support irregular or subblocked data. Various scheduling and optimization algorithms have been implemented on top of this precedence scheme and are compared to their commonplace counterparts through a case study.

9:25 am

Cutoff Grade Optimization for Multiple Mining Zones in an Underground Mine

B. King; Independent Contractor, Denver, CO

An important decision for any operational mine is the selection of the cut-off grade. Choosing the correct cutoff grade, which, in turn, determines the mine design and value, is a strategic decision. We present a mixed-integer programming optimization framework whose solution determines the cutoff grades in three different zones for a soon-to-be-operational underground gold mine. Our enumeration strategy, embedded in this optimization framework, provides objective, repeatable solutions for large-scale problems quickly.

9:45 am

Optimal Pillar Placement in an Underground Stoping Mine

L. Sipeki[1], A. Newman[1] and C. Yano[2]; [1]Operations Research, Colorado School of Mines, Littleton, CO and [2]Industrial Engineering and Operations Research (IEOR), University of California, Berkeley, Berkeley, CA

Underground mine design optimization for a top-down, open-stope retreat operation consists of determining which blocks should be designated as support pillars (and left in situ) and which should be designated as stopes (and extracted and processed) to minimize the ore left in situ (i.e., in the pillars). Constraints in making this selection consist of geotechnical restrictions (pillar stress, hydraulic radius, pillar length-to-width ratios and stope-to-pillar extraction ratios) as well as "common sense" packing constraints. Geotechnical constraints are difficult to express and the resulting problem instances are large and complicated to solve. Therefore, we devise a constructive heuristic; this method exploits our integer programming structure to produce a structurally stable pillar placement design that increases mine profitability by: (1) shifting the pillars to find the most desirable stopes to extract, (2) minimizing the ore left in pillars, and (3) reducing the total cost of stope slotting by creating fewer pillars. We demonstrate the quality of our solutions using data from a real-world mining instance.

10:05 am

Linear Models for Stockpiling in Open-pit Mine Production Scheduling Problems

M. Rezakhah; Economics, Colorado School of Mines, Golden, CO

The open pit mine production scheduling (OPMPS) problem seeks to determine when, if ever, to extract each notional, three-dimensional block of ore and/or waste in a deposit and what to do with each, e.g., send it to a particular processing plant or to the waste dump. Spatial precedence constraints are critical in this type of scheduling problem, as are resource capacities. Certain mines use stockpiles for blending different grades of material, storing excess mined material until processing capacity is available, or keeping low-grade ore for possible future processing. Common models assume that material in these stockpiles, or ``buckets," is theoretically immediately mixed and becomes homogeneous. We consider stockpiles as part of our open pit mine scheduling strategy, propose a new integer-linear model to solve the OPMPS problem, and compare the solution quality and tractability of thr proposed integer-linear and existing nonlinear-integer models. Numerical experiments show that our proposed model is tractable, and correspond to instances which can be solved in few seconds up to a few minutes in contrast to previous nonlinear models that fail to solve.

10:25 am 17-055

Employing Operational Excellence to Optimize Underground Haulage Systems

Y. Sun and J. Sidhom; Joy Global, Franklin, PA

As the mining industry continues to face difficult challenges the need to persistently focus on productivity and utilization of labor and equipment costs will intensify. With these challenges in mind, Joy Global is helping to bring mining performance and analytics to the next level. By evaluating underground haulage, a significant component of the Room and Pillar mining value stream, variables have been identified and sensitivities have been performed to show opportunities to balance and streamline throughput. As a result of applying operational excellence tools to the mining environment, Joy Global is seeking to optimize mining performances by limiting waste, simplifying the process, increasing productivity and machine utilization, as well as removing workers from harm's way.

WEDNESDAY, FEBRUARY 22

MORNING

9:00 am **Room 503**

Mining & Exploration: Operations: Continuous Improvement in Surface Operations

Chair: *J. Dufek, Freeport-McMoRan, Phoenix, AZ*

9:00 am

Introduction

9:05 am 17-016

Benefits of Fragmentation Optimization on the Total Mining Value Chain

R. Riggle, J. Peterson and p. Mckneight; Cat Global Mining, Menomonee Falls, WI

In today's tough mining environment, the key difference between surviving and thriving is how effectively miners optimize their mining operations. This paper explores the compounding effects material fragmentation has on mining costs and productivity. Starting with Drilling & Blasting and moving through Loading, Hauling and Crushing, we will illustrate the opportunities to improve operating costs and thus reduce the Total Cost of Ownership of the Total Mining System. Material size and volume requirements are defined by the needs of the mill or plant, and drive the rest of the mining operation from the bench through the primary crusher. At the start of the cycle, where the rock mass is drilled and blasted, the degree of fragmentation and the muck pile configuration is determined, as are the effects on cost and productivity of all subsequent operations. The cost of managing oversize material, including secondary handling, overloading, reduced diggability, higher load factors, extra pass loading, increased wear factors and reduced throughput rates are all opportunities for improvement.

9:25 am 17-044

Drill & Blast Implementation Case Study at Multiple Sites Within Freeport McMoRan Inc

C. Calderon-Arteaga[1], S. Gering[1], L. Gutierrez[1] and T. White[2]; [1]Hexagon Mining, Tucson, AZ and [2]Freeport McMoRan, Tucson, AZ

Mines are inundated with information from multiple systems and sensors. Despite the wealth of data, many sites struggle to use this information due to challenges with generating meaningful and repeatable analyses. This case study will discuss a Drill&Blast solution that was implemented at Freeport McMoRan Inc. This project required extracting fragmentation, consumables, and other blasthole information from the individual sites and the corporate data warehouse. The data extracted helped users make informed decisions, evaluate, and improve processes. This paper will review the current solution, challenges encountered, and some lessons learned from the project.

9:45 am

Start with the Basics, Change the Culture Then Tackle the Hard Ones and Sustain the Change

E. Sellers[1], L. Kennelly[1] and D. Symonds[2]; [1]JKTech, Brisbane, QLD, Australia and [2]Phu Bia Mining, Vientiane, Lao People's Democratic Republic

This paper explores the benefits of creating sustainable improvement on a mine site by identifying challenges and systematically alleviating the cause behind them over a period of time while changing the staff culture to suit. A case study will be discussed which validates the value of ensuring the drill and blast basics are achieved before attempting to overcome the more complex challenges. The operation is a Copper Gold producer in Laos in South East Asia. Reduction in expatriate workforce to create a culture of localisation and local employment led to an inexperienced team needing to meet major in the pit and the processing plant. The stpes in the solution were to reduce the gap between design and implementation, ensure basic blasting techniques were followed, trial alternative blast designs to improve productivity and then implementing a sustainability program A key learning from the experience gained from this case study is that competent practitioners in key positions have a significant influence over the staff culture, and that accurate drill and blast implementation often has an underestimated effect on production efficiency, cost reduction and business risk.

10:05 am

Barrick Goldstrike's "Best in Class" Implementation

J. Anderson; Barrick, Elko, NV

Barrick's Goldstrike property is located on the Carlin Trend in Northeastern Nevada. The Goldstrike site has been in production for 29 years and produced over 42 million ounces. In 2016 Barrick introduced its "Best-in-Class" initiative to optimize production and lower costs. At Goldstrike Open Pit this meant breaking down walls and perceived limits on equipment productivity and challenged what was defined as "good enough" over the years. This presentation will highlight the programs identified, methods for tracking/implementing, and benefits realized at Goldstrike.

10:25 am
Benefits of Using Fleet Management System Technology on Auxiliary Equipment
C. McElman; Customer Value, Mining Services, Modular Mining Systems, Tucson, AZ

Trucks and shovels represent the lion's share of capital and operating costs in large open-pit mines. As such, organizations tend to focus their fleet management efforts on the haulage cycle, with bulldozers, graders, drills and other types of supporting equipment managed less closely. The presentation will explore the opportunities to improve efficiency and minimize waste through the application of fleet management technology to auxiliary equipment. A productivity model for each piece of equipment will be introduced and examined for a collection of open-pit mines. The concepts behind activity-based costing, immobility detection and auxiliary task management will be explained. Opportunities for improvement will be reviewed and evaluated based on supporting data.

10:45 am
Modeling of Haulage Fleet Capacity in Open Pit Mining under Operational Uncertainties
J. Sattarvand and A. Moniri Morad; Mining and Metallurgical Engineering, University of Nevada Reno, Reno, NV

Mining operation resources such as machinery, human and supplies are utilized to attain production planning goals. However, numerous mining operations experience challenges in achieving their target production capacity due to unpredicted factors in the production, among which the haulage fleet performance has a vital role comparatively. The paper describes a new methodology for modeling of haulage fleet capacity under several operational uncertainties. It is based on two key aspects of the haulage fleet operation including trucks dispatching and operation strategies and failure behavior model of the fleet. Initially, the dispatching problem is developed to make a holistic scenario of the truck hauling framework and to predict the maximum achievable production capacity in the absence of fleet breakdowns and other mechanical failures. Then, these factors were imposed on the chosen model to incorporate the effect of fleet age according to existing maintenance policies. Finally, loss of production capacity due to fleet wear-out rate is quantified in a medium-term planning range. The process is verified through a real copper open pit mine operation and validated with actual experiences.

11:05 am 17-073
Improving Diesel Quality Reduces Cost and Emissions
R. Miller; Reliant Energy Solutions LLC, HIGHLANDS RANCH, CO

Diesel is a key ingredient and cost component in profitable mining operations, fueling haul trucks and onsite power generators. Without fuel, the mill has no ore to process into a product to generate revenue. The inevitable fuel quality deterioration adds both operational and financial costs in high humidity or cold environments. With today's tight commodity margins and environmental regulations, extracting the most value from fuel expenditures, using it efficiently, and reducing toxic emissions is an important concern. New technologies exist to improve combustion efficiency, lower fuel consumption, costs, and emissions, while extending maintenance intervals.

WEDNESDAY, FEBRUARY 22

MORNING

9:00 am **Room 504**

Mining & Exploration: Technology: Generating Value through Technology – Justifying Technology Investments in a Cyclical Industry

Chairs: *L. Fountaine, OSIsoft, Knoxville, TN*
P. Zalevsky, OSIsoft

9:00 am
Introduction

9:05 am **17-056**
Energy Analysis is a Key for Miner Profitability

R. Miller; Reliant Energy Solutions LLC, HIGHLANDS RANCH, CO

Energy comprises 20-30% of overall mining costs and up to 40% of processing costs, and therefore, is a key ingredient to profitable mining operations. How many miners spend the corresponding amount of time on the energy ingredient versus other drivers of their profitability? The different components of energy analysis include price, timing and amount of demand onsite, reliability, generation fuel pricing and access, opportunity cost for loss of energy, efficiency in energy use, backup power, and renewable energy. With today's tight commodity margins, better understanding of energy can reduce costs for increased profitability.

9:25 am
Benefits of Instrument Automation and Integration in a Cyclical Mining Industry

W. Conrad and A. Neuwirt; Canary Systems, Inc., Tucson, AZ

No matter if the mining industry is in an economic upswing or downswing, mine monitoring programs must continue to ensure a safe working environment for employees and assist in preventing a geotechnical or environmental disaster. Many sites currently rely on the manual collection and entry of data for this type of risk management. While manual collection may initially seem more appealing due to lower upfront costs, an automated system allows for reduced long-term expenses and provides a higher risk reduction by allowing an output of more timely, actionable information through periods of both prosperity and recession. By integrating automatically collected data from multiple instrument types into a single system, mine sites can gain a real-time, comprehensive view of the geotechnical and environmental characteristics of their site. As the economic cycle in the mining industry continues to spin, automated monitoring systems allow sites to consistently ensure a high level of risk assessment to provide employee safety and assist in protecting company assets. This paper will explore how the automation of instrumentation affects mine sites throughout the highs and lows of the industry.

9:45 am 17-112

Technological Innovations that Captured Significant Project Value at Peña Colorada over the Past Decade

R. Vivas[1] and J. Villa Mena[2]; [1]Mintec, Tucson, AZ and [2]Mine Planning, Pena Colorada, Colima, Mexico

Located in the state of Colima, Peña Colorada is one of the largest iron ore operations in Mexico. The project is owned in equal parts by ArcelorMittal and Ternium. Though boasting a production capacity of 4.5 million tons of concentrate per year, Peña Colorada has been faced with declining ore grades. In order to respond to this situation, Peña Colorada had to expand production even further. This expansion created various challenges that were overcome by the adoption and application of new technology. Examples of these technological innovations are discussed in detail in this presentation. They include improvements in geo-modeling, mine planning, ore control, and mine operations. The successful implementation of these technologies paid for itself many times over, as it has led to significant improvements in production and performance, while lowering the operating costs and reducing the variance between planning and execution.

10:05 am

Optimization of Crushing and Grinding Circuits for Improved Recovery and Production

M. McGarry; ANDRITZ AUTOMATION, Bellingham, WA

KGHM International's Ajax project is proposing a mill consisting of staged-crushing and grinding followed by a flotation process. The overall copper recovery, final concentrate grade and plant throughput are dependent upon the liberation characteristics of minerals achieved during comminution stage. This paper focuses on the study of changing various process parameters: feed rate, ore hardness, size distribution, circulating load- on overall circuit performance expressed in terms of energy consumption and the degree of liberation prior to flotation. ANDRITZ' simulation tool IDEAS was employed to effectively model the main equipment of the plant: Gyratory Crusher, Cone Crushers, HPGRs, Screens, Ball Mills and Cyclones. IDEAS objects were also used to simulate the function of ancillary the equipment such as, conveyors, apron feeders, pumps, valves, launders and pipes. The dynamic model also included the PID control loops to maintain the process within the limits of operation. The IDEAS objects employed advanced energy and population balance models to evaluate the performance of closed and open size-reduction circuits of the plant.

10:25 am

Investing in Advanced Digital Technologies to Optimize Total Cost of Ownership

D. Richardson; Stantec, Tempe, AZ

Abstract: With a global shortage of local, skilled labor, the development of deeper and larger mines, and an industry-wide push for zero harm, investing in advanced digital technologies is, at first glance, a hard sell amidst persistent budget pressures in a cyclical mining environment. In fact, the implementation of advanced digital technologies reduces the overall cost of asset ownership, by improving safety in the workplace and optimizing productivity while also reducing unplanned downtime and assisting the efforts of mine maintenance personnel. The presentation provides an overview of some of the most value-generating applications of digital technology, including machine health monitoring, advanced diagnostics devices, ventilation-on-demand, digital safety and process interlocks, and high-speed wired/wireless communication networks.

10:45 am
Cortez – Moving to the Digital Age
K. Marten; Tech Services, Barrick, Elko, NV

Barrick has committed to bringing current operations into the digital age to maximize on savings by making processes more efficient and Barrick Gold is undergoing a digital evolution, rethinking the way our business is currently run and bringing ourselves forward into the 21st century. This will be an overview of the early phases of implementation at the Cortez Open Pit. Looking at our current procedures and identifying areas for improvement and how to capture the potential economic upside to justify capital expenditures. There will also be a brief overview of lessons learned to date.

WEDNESDAY, FEBRUARY 22
MORNING

9:00 am **Room 502**
Mining & Exploration: Technology: Highwall Laser Scanning & Photogrammetry

Chair: *B. Haugen, Maptek, Golden, CO*

9:00 am
Introduction

9:05 am
Design Conformance Reporting and Highwall Mapping with Laser Scan Data
B. Barnum; Survey, Barrick, Elko, NV

Cortez, like most mines is faced with many geotechnical and safety challenges. High wall scanning and photogrammetry are two main methods we use to overcome these challenges, and with the use of the Mapteks I-Site 8800 series scanners these two remote sensing methods are seamlessly combine into one process. The process is as simple as setting up in a few remote locations and acquiring the LiDAR data and georeferenced images with the scanner. Once processed and registered with the corresponding GPS locations the data can then be utilized in many different ways. The first way is geotechnical conformance reporting. We are able to quickly and accurately determine whether a high wall has been mined to design. We can determine the amount over dug and under dug all with a high resolution georeferenced imaged overlaid with a heat map. We can also extract cross sections and produce reports on the overall face angles and inner ramp angles of a final pit. This data can then be shared with the operations group to improved operator efficiency. The next way is using the georeferenced images to perform high wall mapping with the need to approach the high wall.

9:30 AM

Using Maptek's I-Site Studio to Optimize Structure Pit Mapping and Modeling

J. Cobb; Geology, Member, Bagdad, AZ

Large, surficial structure data sets compiled over decades, and by multiple exploration and pit geologists, can at times be difficult to unify, interpret, and ultimately model. By utilizing Maptek's laser scanner and I-Site Studio in conjunction with ground truething efforts, these challenges can be addressed more intuitively. Using the geotechnical tools suite along with the major I-Site studio functions the modeler can create a 3D, GIS-like database where outcropping faults and joint populations can be identified, visualized, categorized, prioritized, and directly measured within the context of their in-situ, 3D locations. Attachments such as notes and images can also be directly applied to various data sets in order to assist with interpretation and preserving continuity across benches. Geostatistical analysis is streamlined with in-software capabilities allowing the modeler to make multiple, and locality-specific, interpretations. Additional noteworthy benefits from this application include: the generation of high-resolution, bench highwall surfaces, useful for design vs. actual analyses; and the generation of projected fault and joint planes, useful in pattern design.

9:55 am

3D Laser Scanning & Geotechnical Software for Safely Mapping Highwalls

N. Goncalves; I-Site Technical Services, Maptek, Lakewood, CO

Safety in the mining industry is a primary concern worldwide. Employing the use of new technologies allows for increased safety across sites; one way of doing this is by removing the placement of staff in dangerous situations. The way to remove personnel from active areas without sacrificing data is by using remote sensing systems, primarily we'll focus on laser scanning. This presentation will highlight specific case studies that illustrate the benefits of 3D laser scanning & geotechnical software for analyzing open pit highwalls. In regards to open pit highwall safety concerns, structure is major factor in determining stability and competence of the rock face. Unfavorable structural orientations, poor rock conditions and steep slope angles in relation to mine design can create dangerous highwall conditions and potential for wall failure. Advancements in 3D laser scanning and geotechnical software allow for geologist / geotech's to analyze point cloud data for structure orientation, spacing, waviness and the ability to create stereonets, rose diagrams and advanced kinematics for detailed analysis.

10:20 AM

Benefits of Combining UAV Photogrammetry and Terrestrial Lidar for Highwall Inspection and Characterization

J. Lyons-Baral[3], J. Kemeny[1], M. Medvec[2] and R. Michaelsen[3]; [1]Mining and Geological Engineering, University of Arizona, Tucson, AZ; [2]Geomatics, Hawkeye AS, Ytre Arna, Norway and [3]Mining, Hexagon, Tucson, AZ

The burgeoning work of unmanned aerial vehicles (UAV) for surveying and remote sensing is perched to take prominence in mining, geology and geotechnical engineering. For highwall inspection and characterization, the acquisition of terrain data by both UAV imagery and terrestrial lidar presents complementary data sets that, when combined, fill in significant gaps in the other's limitations. This presentation features two highwall case studies, both surveyed with a UAV and terrestrial lidar. The resulting point clouds, orthoimagery and video demonstrate the differences of each methodology as well as the benefits of combining the two for mining and geotechnical engineering.

10:45 am
3D Dynamic Monitoring of Displacements by Using Dynamic Close Range Photogrammetry

S. Ghaychi Afrouz[3], M. Razavi[1], A. Pourkand[4], S. Amirrahmat[5] and C. Wilson[2]; [1]Mining, New Mexico Tech, Morenci, AZ; [2]Civil Engineering, New Mexico Tech, Socorro, NM; [3]Mining and Mineral Engineering, Virginia Tech, Blacksburg, VA; [4]Mechanical Engineering, The University of Utah, Salt Lake City, UT and [5]Civil Engineering, University of Tennessee-Knoxville, Knoxville, TN

This study describes application of a non-contact technic to monitor the 3D dynamic displacements of structures using digital videos captured by two or more synchronized digital cameras. This method is based on the principles of Close Range Photogrammetry (CRP), the science of using photographs of a nearby object for accurate measurements. This method not only can precisely monitor displacements of virtually unlimited number of points with time in all directions to measure movement of critical infrastructures, but also is helpful for 3D monitoring of the remote areas where traditional dynamic monitoring instruments such as accelerometers cannot be installed. To investigate the applicability and accuracy of CRP to monitor dynamic displacements, a small scale model of a one-story building was built on a shake table. The structure was shaken, and the displacement time history of it was obtained by using two different methods: accelerometers as the conventional contact method and dynamic CRP as the non-contact method. Additionally, the displacement time histories were compared to the results of a simple mass and spring model and its results were very similar to Dynamic CRP method.

WEDNESDAY, FEBRUARY 22

MORNING

9:00 am **Room 709**

MPD: Alternative and Bioleaching Systems

Chairs: *R. Gow, Midvale, UT M.Melashvili, University of British Columbia, Peterborough, ON, Canada*

9:00 am
Introduction

9:05 am **17-034**
Demonstration Campaign Results on a Cyanide Free Process for Gold Extraction from a Refractory Pyrite Concentrate

A. Drouin, D. Lemieux, J. Lalancette and C. Chouinard; Dundee Sustainable Technologies, Thetford Mines, QC, Canada

A gold bearing pyrite concentrate was treated at the demonstration scale (15 t/d) for the extraction of gold using a cyanide free process. The pyrite is depressed in the flotation circuit in order to promote the flotation of copper and to achieve a sufficient copper grade to meet the copper smelter criteria. However, the recoveries of copper were 80% and only about 50% for the gold in the copper concentrate. The balance of the gold (50%) and copper (20%) are contained in the pyrite concentrate as a reject from an overall flo-

tation circuit. The gold grade in the pyrite concentrate is 6 g Au/t and copper is about 0.9%. About 170 tons of pyrite concentrate were processed in the DST demonstration plant. The concentrate was first oxidized using a fluid bed to produce a calcine. Copper was then extracted as copper sulphate using diluted sulfuric acid. The residual solid was submitted to the DST chlorination process for gold extraction. Thereafter, the gold was recovered from the pregnant brine by precipitation over silica using DST proprietary process. The maximum gold recovery by chlorination was 90% with an average of 81%. The average recovery by cyanidation was 71%.

9:25 am

Cost Evaluation for AuBrLSX - a Fully Recycled Bromine/Bromide Leach and Solvent Extraction Process for Recovering Gold from Gold Ores

R. Birnbaum[1], S. Krumbein[1], R. Costi[1], K. Larmour-Ship[2] and T. Fabian[2]; [1]ICL, Beer-Sheva, Israel and [2]Tenova, Yoqneam, Israel

In the last two years, AuBrLSX, a self-contained bromine/bromide process for leaching and recovery of gold from gold ores using solvent extraction was developed. The recent work reveals equal or superior gold recoveries compared to cyanide for oxide and sulfide ores. Earlier work is presented that demonstrates the process advantage over cyanide for high cyanide-soluble copper ores. The process is a completely recycled system using electrochemical regeneration of the reagent. The inclusion of solid/liquid separation and Pregnant Leach Solution (PLS) pre-treatment and raffinate stream post-treatment provide the advantage of benign tailings, minimal reagent bleed and make-up. Clean water is available for recycle to the grinding circuit. This process demonstrates competitive operating costs compared to the cyanide process. The mass and energy balance that allowed the calculation of these costs was performed on METSIM, a process simulation software. An order-of-magnitude capital estimate for the leach and gold recovery portion of a theoretical plant is presented.

9:45 am 17-014

Assessing the Challenges in the Extraction of Gold from Bacterial-Treated Double-Refractory Concentrate

A. Adam[2], G. Ofori-Sarpong[1] and R. Amankwah[1]; [1]Minerals Engineering, University of Mines and Technology, Tarkwa, Ghana, Tarkwa, Ghana and [2]Processing, Golden Star Resources Ltd, Bogoso/Prestea Mine, Tarkwa, Ghana

In the application of the BIOX® technology, high tailings grade (2-16 g/t) are sometimes generated with a decrease in overall gold recovery, which sometimes make it economically unattractive. This paper investigated the causes of the high tailings grade by using samples from the Bogoso BIOX plant. Partial chemical analysis, diagnostic tests and cyanidation optimisation studies were conducted to invoke understanding into the high tailings grades. Diagnostic study on the tailings showed 48.34% of gold in carbonaceous matter, 17.12% in quartz, 13.40% as liberated gold, 11.51% imbedded in sulphides and the remaining 9.65% in carbonates. Optimum cyanidation recovery of 90.4% was established for the BIOX concentrate at 7 kg/t NaCN, 40-50 g/L activated carbon and residence time of 40 hours. The recovery was sensitive to carbon and cyanide concentrations but additional cyanide was not economical. High preg-robbing indices of 72.7% and 64.4% were recorded for the BIOX product and the flotation concentrate respectively. This confirms the inability of the BIOX process to deactivate carbonaceous matter, which remains a serious precursor for low overall gold recoveries and high CIL tailings.

10:05 am

Leaching PGMs from Spent Automotive Catalysts by Biogenic Cyanide

D. Shin[1], J. Lee[1] and J. Lee[2]; [1]Korea Institute of Geoscience and Mineral Resources, Daejeon, Korea (the Republic of) and [2]Department of Mining and Geological Engineering, University of Arizona, Tucson, AZ

Cyanide was produced and accumulated by Chromobacterium violaceum using a noble two-stage processes to achieve maximum cyanide concentration. Batch reactor and continuous reactor showed maximum cyanide concentrations of 955 ppm and 6595 ppm, respectively. Using biogenic cyanide, Pt, Pd, and Rh were leached from the spent automotive catalyst and the results were compared with the performance of a cyanide solution prepared by a chemical NaCN. The extraction percentages of Pt, Pd, and Rh using 1000 ppm biogenic cyanide at 150°C was 92.1%, 99.5%, and 96.5%, respectively. Sodium cyanide solution with 1000 ppm under the same conditions showed the metal extraction of 100%, 99.9%, and 100%, respectively. It is believed that dissociated anions and oxygen in biogenic cyanide causes lower metals extractions but it was not significant. Detailed culturing methodologies to accumulate a high concentration of cyanide in the system will be discussed. The leaching methods and comparative discussion on metal leaching in biogenic cyanide and chemical NaCN will be discussed.

10:25 am 17-017

Enhancing the Biooxidation of Secondary Sulfides and Improving Commerciality in a Cyclical Copper Market Lisbon Valley Mining Co LLC San Juan County UT

L. Indergard; Environmental, ISR, Aeration, Lisbon Valley Mining Co LLC, Moab, UT

Intro The Lisbon Valley Mining Co LLC (LVMC) owns and operates a copper mine in southeast Utah. Metallurgical Issues Copper production from secondary sulfides is constrained by permeability issues, gradation (>6 in.) and available oxygen. Enhancing Biooxidation Due to the higher activation energies of copper sulfide minerals, a strong oxidant is needed to remove an electron from the metal-sulfide lattice and release the copper cation into the sulfate solution. This process occurs most efficiently using the strong oxidant ferric iron ($Fe3+$). Ferrous iron can be oxidized to ferric iron by oxygen via chemical oxidation or biologically. Forced Aeration System Design This paper describes LVMC's efforts to improve production by biooxidation. Production Analysis The biooxidation system is effective. Copper netting has increased. The netting is closely monitored and is highly sensitive to leach rates, as these relate to degree of saturation. Pre-aeration and post-aeration geochemical characteristics (most importantly eH) and copper production data will be presented to demonstrate the efficacy of the biooxidation processes.

10:45 am

Engineering Acidithiobacillus Ferrooxidans for Biochemical Production

S. Banta and A. West; Chemical Engineering, Columbia University, New York, NY

Bacteria involved in bioleaching, such as Acidithiobacillus ferrooxidans, may be unique new platform organisms for biochemical production as they are able to use CO2 as a carbon feedstock while deriving energy from the oxidation of iron or sulfur. We have recently genetically modified A. ferrooxidans cells with two different metabolic pathways. One cell line is able to produce isobutyric acid and another cell line produces heptadecane from CO2. We have also been exploring new endogenous promoter sequences to enable metabolic control over product formation. Media optimization experiments in chemostat cultures have been performed, and wild type cell growth, yield, and maintenance are improved when an iron chelator (citrate) is included. This enables growth at higher pH and reduces ferric inhibition, and these additions also significantly improved the production of isoburyrate and heptadecane. We are exploring the production of biochemicals during the oxidation of sulfide rich ores, which could result in the economic co-generation of biochemicals during biomining operations – proving that reduced metals in the Earth's crust may be an untapped feedstock for biochemical production.

WEDNESDAY, FEBRUARY 22

MORNING

9:00 am **Room 703**

MPD: Comminution I

Sponsored by Moly-Cop USA, LLC

Chairs: *M. Larson, Glencore Technology, Ewen, MI*
O. Arafat, Metcom Technologies, Hamilton, ON, Canada

9:00 am

Introduction

9:05 am

A New Rod Mill Installation at Cripple Creek and Victor Gold Mine, Colorado, USA

W. Thurman and Z. Zanetell; Cripple Creek & Victor, Newmont Mining Co, Woodland Park, CO

It has been nearly 30 years since a new rod mill was installed as a primary comminution unit in a gold operation in the United States. In 2014/2015 a new 13.5' x 20' rod mill was installed and commissioned at Newmont's Cripple Creek and Victor Gold Mine (formerly Anglo Ashanti). While this may appear to be a step backwards in grinding technology, rod mills may have certain advantages over other grinding processes in specific applications. This paper examines the decision process, the installation, commissioning, metallurgical/operational benefits and limitations of the rod mill at CC&V's new gold concentrator.

9:25 am

Methodology to Predict Product Size Distribution of a Vertical Stirred Grinding Mill Using Bond's Ball Mill

D. Rocha; Mining, Colorado School of Mines, Golden, CO

The fine, re-grind, and ultra-fine comminution processes are energy intensive resulting in high operating costs. The use of conventional ball mills for grinding in fine size ranges is inefficient and, therefore, vertical stirred mills are becoming increasingly popular in the mineral processing industry. This work presents hypotheses of a new methodology to predict the product size distribution of a vertical stirred grinding mill using the population balance method. Initially, detailed experimentation was carried out in a Bond's batch ball mill and the breakage and selection functions were determined for the aggregate material tested. After collection of the breakage parameters, it was possible to predict the product size distribution as a function of grinding time. The aim of this work is to use the breakage parameters determined from the Bond`s batch ball mill test to predict the product size of a vertical stirred mill. The effects of changing the mill`s rotation velocity on the final product size distribution may be demonstrated through this methodology and optimization of grinding performance can be assessed.

9:45 am 17-015

Ball Mill Classification System Optimization Through Functional Performance Modeling

R. McIvor, O. Arafat and K. Bartholomew; Metcom Technologies, Hamilton, ON, Canada

The Functional Performance Equation calculated from a plant grinding survey defines two distinct efficiencies and how they relate to total production rate through the target grind size. The survey data are also used to calculate a complete ball mill size distribution model, represented by the energy specific grinding rates through all the size classes. Cyclone separation performance is represented by individual size recoveries to underflow. When these two unit operation performances are entered into the circuit modelling program, along with the circuit feed rate and size distribution, all the circuit survey size distributions and mass flows are perfectly re-generated. The many problems encountered with historical breakage-selection-RTD models are eliminated. Once the circuit program is populated, pump and cyclone performance changes can be evaluated using a step by step procedure in order to maximize Classification System Efficiency. Mill water use and media sizing opportunities can also be diagnosed in order to maximize Mill Grinding Efficiency. Case studies are presented. This circuit analysis and modelling system and related training, is provided through a web-based application.

10:05 am 17-114

The ABC of Mine-to-Mill and Metal Price Cycles

D. Drinkwater[3], J. Pease[2], P. Cameron[1] and T. BoBo[1]; [1]Split Engineering, Tucson, AZ; [2]Mineralurgy, Brisbane, QLD, Australia and [3]MINERALIS Consultants, Brisbane, QLD, Australia

In the 1990's metal prices trended in a long term decline, the usual cost cutting exercises were adopted. This spurred the Mine-to-Mill movement which optimised operations across organisational "silos", utilized new tech tools and innovative software. Many applications of Mine-to-Mill exploited the fact that comminution is the bottleneck and that blasting is more efficient at breaking rock than grinding. This approach sought to: -Understand and characterize rock breakage from mine to the mill -Develop models and simulators for blast design, fragmentation, crusher and mill circuits -Develop tools to measure in real time the PSD of ore on conveyors and ROM -Ensure effective communication across the silos In the minerals price boom of the 2000's Mine-to-Mill was no longer necessary to "survive", even if it was good business. The boom has ended and operations are again under cost pressure. Since the 1990s many new or advanced technology tools are now available for Mine-to-Mill projects: If we could achieve so much in the 1990's, how much more can we achieve today when we have the same imperative, the same potential and a larger number of high technology tools?

10:25 am

Improving Advanced Control in Grinding Areas to Maximize Mineral Throughput and Better Size Classification

T. Carricajo[1] and D. Silva[2]; [1]Automation, Andritz Chile, Las Condes, Chile and [2]Los Pelambres, AMSA, Santiago, Chile

As in many ore processing plants, in AMSA-Los Pelambres the main objective of the grinding control is to maximize the SAG mill throughput and increase size quality by minimizing P80. Therefore, advanced control team has implemented an ongoing learning process that allows for continuous improvement of the control system. To better meet these demands, two advance control layers were devised and implemented; both for primary and secondary grinding areas. The lower layer objective is to stabilize the process based on model-based predictive control tools, chosen by its good stability and convergence. The upper layer is the optimizing one; which increases performance and automatically adapts its conditions to changing ore and process conditions. After several months of operation, results show an increase in throughput up to 2% and decreased P80 up to 30 microns. As a secondary effect, the energy consumption has decreased about 2-5%. It is believed that this represents a great advance over known control strategies because it adapts itself to changing scenarios, anticipates disturbances and incorporates process behavior knowledge. It represents a further step towards man-less operated plants.

10:45 am

Liberation and Release of Rare Earth Minerals from Coal Sources

A. Noble[1], J. Herbst[1], Q. Huang[1], G. Luttrell[2] and R. Honaker[3]; [1]Mining Engineering, West Virginia University, Morgantown, WV; [2]Mining and Minerals Engineering, Virginia Tech, Blacksburg, VA and [3]Mining Engineering, University of Kentucky, Lexington, KY

Recent studies have shown that coal and coal-related materials may be promising sources of rare earth elements (REEs). For pre-combustion coal and coal refuse, the REEs often exist as ultrafine mineral grains less than 10 microns and in dilute concentrations between 300 to 600 PPM (whole sample basis). In an effort to better understand the association and liberation of REEs from the organic and inorganic constituents, a laboratory REE release testing procedure was designed and employed on a coal preparation middling product from east Kentucky Fireclay coal. In these tests, -1 mm middling material was ground in a laboratory ball mill for a specified energy input, and the grinding product was then decarbonized using a combination of heavy liquid separation and staged flotation. The REE content of the high ash tailings and low ash concentrate was determined, and the process was repeated for various target grind sizes down to the micron range. The results indicate that smaller grind sizes produce increased REE concentration in the high ash tailings. Furthermore, an economic assessment shows the tradeoff between the value of the released REEs and the grinding energy cost.

11:05 am 17-064

Experimental and CFD Investigations of the Fluid Flow Inside a Hydrocyclone Separator with an Air Core

r. ke[2], J. Kadambi[2], J. Furlan[1], R. Visintainer[1] and C. Shingote[2]; [1]Engineering and R&D, GIW Industries, Grovetown, GA and [2]Mechanical and Aerospace Engineering, Case Western Reserve University, Cleveland, OH

Hydrocyclone separators are widely used in the oil and mining industries to sort, classify and separate solid particles or liquid droplets within liquid suspensions. In this study, the flow field with air core inside the actual hydraulic

geometry of a milling circuit hydrocyclone was explored with the aid of both computational and experimental techniques (Particle Image Velocimetry). The numerical simulations were conducted by the commercial software, Star CCM+, and two turbulence models were used: the Reynolds Stress Turbulence Model (RSM), and the Large Eddy Turbulence Model (LES). Additionally, the computational studies also focused on the prediction of the dimensions and shape of the air core. Particle Image Velocimetry (PIV) technique was used for the experimental measurements along with refractive index matching. The model hydrocyclone was made of optically clear acrylic. Numerical results are compared to the experimental data. The local fluid velocities, as well as the shape and diameter of the air core and the physical time scale of air core generation were in good agreement with the experimental results when the LES model was applied.

WEDNESDAY, FEBRUARY 22

MORNING

9:00 am **Room 707**

MPD: Flotation of Sulfide Minerals

Chairs: *R. Kappes, Newmont Mining Corp, Englewood, CO*
B. Aksoy, Missouri University of Science and Technology, Sandersville, GA

9:00 am
Introduction

9:05 am
Water Chemistry Effects on the Flotation of Gold Ores: Role of Salinity, Ca^{2+} and Mg^{2+}
E. Arinaitwe, J. Jankolovits, D. Nagaraj, M. Chin and R. Farinato; Technology Solutions, Cytec Solvay Group, Stamford, CT

Past studies have suggested that calcium ions and other dissolved species in process water detrimentally impact the flotation recovery of gold from primary Au and Cu-Au ores, and this appears to be a prevailing belief in industry. A number of flotation circuits are operated in low pH or low Ca^{2+} conditions out of such aquatic chemistry concerns. The increasing use of saline process water, such as sea water, in the industry due to restrictions on freshwater access further complicates the aquatic chemistry of gold ore flotation pulps. However, the impact of process water salinity on real ores is uncertain given the convolution of factors that influence flotation and the limited correlation between single-mineral studies and practical systems. In this study, we probe the effects of solution species on the surface chemistry and flotation of gold-bearing sulfides using electrochemical and batch flotation techniques in different types of waters to gain insights on the impact of water chemistry on Au recovery and processing strategies.

9:25 am

New Reagent Schemes for Improved Metallurgy in Cu-Ni Ore Flotation

N. Tercero and D. Nagaraj; Cytec Solvay Group, Stamford, CT

Processing strategies for Cu-Ni and Ni sulfide ores by flotation are largely dictated by the predominant gangue minerals (altered Mg silicates, iron sulfides, or both) and the amount of Cu. Historically, xanthates have been used, almost exclusively, irrespective of the ore type. However, xanthates alone cannot offer the flexibility and metallurgical performance required to meet the processing challenges. In this paper, we discuss specific advantages that can be realized in practice with new reagent schemes based on a broader spectrum of chemistries which allow the flexibility to design strategies to improve metallurgy in the processing of Cu-Ni ores.

9:45 am

TKI 330 - an Alternative Reagent for Depression of Copper and Iron Sulfides in Molybdenite Flotation Circuits

A. Dimitriadis and T. Cook; Tessenderlo Kerley Inc, Phoenix, AZ

One of the most common methods utilized to separate Molybdenite from Copper and Iron sulfides involves depression of the latter species from the feed slurry with sodium hydrosulfide (NaHS). Process operations are significant, with typically several rougher and cleaning stages required to generate a suitable final concentrate. The focus of this work is the evaluation of the effectiveness of an alternate reagent, TKI-330, as a substitute for NaHS in the floatation/depression circuit. TKI-330 is a water-based Polysulfide solution, and presents significant safety, health and environmental advantages over the use of NaHS, primarily due to its lower H_2S exposure potential. Laboratory studies were conducted at five sites, as well as a full-scale plant trial. Results indicated TKI-330 provided comparable separation efficiencies relative to the use of stock NaHS solutions, and, in plant trial, the potential to simplify the moly floatation/depression circuit–operations with TKI-330 utilized fewer cleaning stages than stock NaHS, and did not require the addition of any frother or pH adjustment chemicals. Lastly, process operations were noticeably less malodorous during the use of TKI-330.

10:05 am

Effect of Particle Aspect Ratio in Flotation

T. Bhambhani[1], D. Nagaraj[1], R. Farinato[1] and P. Somasundaran[2]; [1]Cytec Solvay Group, Stamford, CT and [2]Earth and Environmental Engineering, Columbia University, New York, NY

Dilution of concentrate grade by differential transport of high aspect ratio non-sulfide gangue minerals (e.g. mica) to the froth phase is a common problem in several operating plants. The particle transport mechanisms into and through the froth phase as a function of aspect ratio is poorly understood. Experiments carried out by preparing particle mixtures with varying aspect ratio distributions revealed that aspect ratio significantly affects transport. Studying the aspect ratio effects as a function of particle size revealed non-linear interactions between the two variables. This paper discusses differential transport in consideration of the onset of critical aggregation phenomena in the froth phase.

10:25 am

Exposed Grain Surface Area Analysis of Coarse Particle Flotation

Y. Wang, C. Lin and J. Miller; Metallurgical Engineering, University of Utah, Salt Lake City, UT

Now due to advances in high resolution X-ray microtomography (HRXMT) with a voxel resolution less than 1 micron and the development of advanced image processing algorithms, it is possible to identify dispersed grains as small as 5 microns in multiphase particles and quantify their surface area exposure in 3D. Analysis of products from the coarse particle flotation of an auriferous pyrite ore demonstrate that two levels of analysis need to be considered in the flotation of locked particles. At the first level, the particle distribution with respect to exposed grain surface area, expressed as a percentage of the total particle surface area, must be considered. The results demonstrate the ability of HydroFloat flotation to recover locked coarse particles with as little as 1% exposed grain surface area. At the second level, the grain distribution with respect to actual exposed surface area must be considered in order to describe stability of attached air bubbles. It was found that particles having a maximum exposed grain surface area less than ~16000 mm^2 have a poor flotation response and will be recovered in the tailings.

10:45 am 17-066

Flotation of Problematic Cu-Zn Ores in CBI (Tuerkey)

Z. Ekmekçi[1], O. Bicak[1], M. Can[1], I. Celik[1], Y. Ozturk[1], B. Kocabiyik[2] and N. Arslan[2]; [1]Mining Engineering Department, Hacettepe University, Ankara, Turkey and [2]Cayeli Bakir Isletmeleri A.S., Rize, Turkey

In this paper, a case study from Cayeli Bakir Isletmeleri A.S. (Rize, Turkey) about the selective flotation of copper minerals from sphalerite is discussed. Cayeli Cu-Zn Sulfide Ore contains different ore types, such as yellow ore, clastic ore, bornite-clastic ore, bornite-yellow ore, and black ore. For some of these ore types, selective flotation of copper and zinc is very difficult presumably due to presence of secondary copper minerals such as bornite, chalcocite and covellite, and also surface oxidation. These factors affect Cu-Zn selectivity due to activation of sphalerite particles in the ore during the process The main objective of this work was to improve Cu-Zn selectivity by optimization of the pulp chemistry for different ore types of Cayeli ore. After preliminary flotation tests investigating effects of different chemical conditions, a plant survey was performed to determine the plant performance and sources of the problems when problematic bornite-clastic ore is treated in the plant. Various chemical conditions are tested in the laboratory scale test for better depression of sphalerite in copper flotation circuit.

11:05 am

The Use of Quebracho Tannins in Froth Flotation

J. Rutledge[1] and C. Anderson[2]; [1]Metallurgical and Materials Engineering, Colorado School of Mines/Silvateam Indunor, Centennial, CO and [2]Metallurgical and Materials Engineering, Colorado School of Mines, Golden, CO

Tannins, a naturally occurring, non-toxic reagent, have shown promise in metallurgical and mineral processing applications. This research was performed to investigate the use of quebracho tannins (specifically Tupasol ATO and Tupafin ATO) in flotation as a depressant. Two ore types, copper and fluorite, were researched. Surface chemistry studies including zeta potential, adsorption density, and microflotation were undertaken to provide fundamental knowledge of the behavior of tannins interacting with the mineral surface.

Microflotation experiments were performed on pure minerals to determine suitable operating parameters for bench flotation; a number of statistical models were generated to predict the outcomes of changing parameters. Three different tannins (Tupasol ATO, chestnut, and wattle) were compared for the microflotation of calcite and fluorite. In bench flotation with the addition of tannins, the recovery and grade of both the fluorite concentrate and the copper concentrates increased. This suggests that tannins not only work as a depressant but as a dispersant. An economic analysis was completed to explore some of the fiscal benefits of using tannins for froth flotation.

WEDNESDAY, FEBRUARY 22

MORNING

9:00 am Room 705

MPD: Plant Design III

Sponsored by Moly-Cop USA, LLC

Chair: *A. House, Hatch, Lakewood, CO*

9:00 am
Introduction

9:05 am 17-115

The Cerro Verde 2 Concentrator: Design, Start Up and Operation

J. Vanderbeek[3], P. Gelfi[1] and J. Enriquez[2]; [1]Sociedad Minera Cerro Verde, General Manager Processing, Arequipa, Peru; [2]Sociedad Minera Cerro Verde, Concentrator Operations Supt., Arequipa, Peru and [3]Freeport McMoran, Manager Metallurgy & Strategic Planning, Phoenix, AZ

The Cerro Verde copper-molybdenum mining complex is located near Arequipa, Peru. A 108,000 t/d copper concentrator (C1 concentrator) commenced operation in late 2006 and was debottlenecked to a 120,000 t/d capacity in 2011. A feasibility study, initiated in May 2010, assessed the potential for expanding the processing rate of the large Cerro Verde sulfide reserve via the installation of a second, stand-alone, concentrator (C2 concentrator) capable of processing a nominal 240,000 t/d ore. The feasibility study was successful and the project advanced through engineering, permitting and construction. Ramp up to nameplate capacity was ahead of schedule. The overall project was completed on schedule and within budget. The details of the project and supporting components are described. The design philosophy and design basis of the concentrator facilities are discussed as are factors that influenced the concentrator layout. Risk mitigation features included in the design are reviewed. The factors that drove the successful and rapid ramp up to nameplate capacity are discussed. Operational experiences in the first year of plant operation and project lessons learned are described.

9:25 am

Newmont Long Canyon: Project Opportunities

N. Brazier; Process, Newmont, Elko, NV

The Long Canyon gold deposit is located along the eastern flank of the Pequop mountains in northeastern Nevada. Four years after Newmont took ownership of Long Canyon in April 2011, the BLM issued a Record of Decision and Newmont's Board of Directors approved full funding of the project. Long Canyon provided an opportunity to bring into production a lower-cost, profitable mine by leveraging the synergies available within Newmont's existing Nevada operations. This has involved a variety of areas including project personnel, previous engineering designs, regional functional area support, conducting some process activities at alternate locations and advantages provided by Regional Asset Management opportunities for mining equipment. In conjunction, Newmont was able to provide continuity, and other pre-construction benefits, to the project with a design/build approach versus a typical EPCM method. Moving into production, Phase 1 will operate utilizing traditional open pit mining methods and feed Run-of-Mine ore to a heap leach facility. A barren cyanide solution will be applied to the heap and subsequent pregnant solution will be collected and recovered to activated carbon.

9:45 am 17-139

A Comparison of Pipe Material and Their Performance in Mine Waters

A. Pezzuto[1], E. Sarver[1] and H. Mischo[2]; [1]Mining & Minerals Engineering, Virginia Tech, Blacksburg, VA and [2]Mining Engineering, Technical University Bergakademie Freiberg, Freiberg, Saxony, Germany

The Reiche Zeche mine field in Freiberg, Germany is a collection of metal mines dating back approximately 800 years which have since been combined to form a single, maneuverable mine. Presently, the mine is a research and teaching facility utilized by TU Bergakademie Freiberg, and the University's partners in research and industry. The variety of water conditions found within Reiche Zeche creates unique challenges for conveyance systems. This is particularly true for pipes, which face a number of issues such as scaling, sedimentation, and corrosion. A polyethylene (PE) 100 pipe has been recently designed with a newly developed interior liner. To test its general performance, it was installed in 6 different sites within the mine along with traditional (unlined) PE 100 pipe and galvanized steel pipe. The scaling effects were analyzed both physically and chemically to determine if the lined PE pipe exhibits any significant advantages over the other pipe materials. Longer term pipe-loop tests are currently being conducted in the laboratory to investigate scaling in multiple water qualities, and complementary tests are also investigating the lined PE pipe's resistance to abrasion.

10:05 am

Dry Stack Tailings? Don't Bother with Filters – a Case Study

A. Accioly, M. McCaslin, B. Misra and S. Patra; WesTech Engineering, Murray, UT

This paper presents a simple solution for dry stack tailings without the use of an expensive filtration stage. The concept involves well proven paste technology and an inexpensive, widely applicable air-drying scheme to permit bulk handling of the tailings using mobile equipment or traditional conveyors. A case study is addressed where the approach was planned and is feasible. Low-risk tailings management need not be horrendously expensive.

10:25 am 17-011

Application of Taguchi's Method to Uncertainty Assessment and Sensitivity Analysis for Mineral Processing Circuits

S. Amini and A. Noble; Mining Engineering, West Virginia University, Morgantown, WV

While many classic separation circuit design methods rely on deterministic approaches, numerous studies have shown that the uncertainty inherent to the input parameters can significantly affect design decisions. In a separation circuit, many of the technical uncertainties can be mathematically represented as statistical distributions for the unit recovery and feed grade. These uncertainties are then propagated by the circuit design and reflected in the circuit performance measures, such as product grade and global recovery. An effective design strategy entails identifying which units are most influential in this uncertainty propagation and thus merit further consideration. One promising approach is through the application of Taguchi's method, in a fashion similar to statistical tolerancing of manufactured products. Since the technical challenges are fundamentally similar, Taguchi's method shows promise in evaluating the level of compounded uncertainty by various circuit designs while determining the role of each separation stage on the overall selectivity and variability of circuits. This paper demonstrates Taguchi's method in several two and three unit circuit designs.

10:45 am

Plant Design and Probability of Success or Failure in Achieving Design Throughput

D. Meadows; Mining and Metals, Bechtel, Phoenix, AZ

Many recent new plants have experienced long ramp-up times with costly retrofitting necessary to reach design throughput. Very often, the original design may have been modified to reduce CAPEX in this "cost-conscious world" of depressed commodity prices. Projects with unusually hard and more competent ores have particularly suffered problems in this regard. In some cases, the ramp up information and nameplate capacity information can be misleading. The emphasis should be on "up-front" process engineering work to achieve the best balance between study costs and the very real risks associated with any mining project development. The up-front work will include appropriate drilling; process mineralogy, acquisition of comminution and process development samples, as well as resource definition samples; adequate and properly conducted test work and procedures; and competent interpretation of test work results into sizing of the major process equipment. If all the process design tasks fall into place, the probability of success will be high. If not, a slow ramp up could completely destroy the financial returns from the project.

11:05 am 17-095

Potash Production Hoisting Plant Upgrade & Beyond

D. Ziebarth; WSP Group, Thunder Bay, ON, Canada

During the mid to late 1960's, the underground potash industry in Saskatchewan was born. For the next four decades the industry operated at a steady pace supporting a large part of the world demand; until 2008 when the potash market heightened. Operators were motivated to capitalize on this increased demand, new mines were proposed while existing mines were planning upgrades. Potash Corporation of Saskatchewan (PCS) was one of the major players looking to upgrade their production facilities quickly, including modifying the existing headframe and shaft at the PCS Cory Site to accommodate a new 1500 tonnes per hour hoisting plant. Upon completion of the project, the innovative operations group continuously reviewed methods to increase production or reduce operating cost, allowing PCS to be competitive on the world market. This paper will describe the design challenges encountered during the development of the infrastructure around an operating facility whilst minimizing down time, schedule, capital and construction costs. The paper will also explore the strategy to squeeze additional capacity out of the newly commissioned hoisting plant.

WEDNESDAY, FEBRUARY 22

AFTERNOON

2:00 pm **Room 708**

Coal & Energy: Breathing Air Supplies

Chairs: *R. Fernando, NIOSH-OMSHR, Pittsburgh, PA*
W. Wedding, University of Kentucky, Lexington, KY

2:00 pm

Introductions

2:05 pm

Deployment of CCERs in Underground U.S. Coal Mines to Meet Current MSHA Standards

J. Kravitz; MEO, MSHA, Pittsburgh, PA

In the past, there has been some confusion about how CCERs (SCSRs) should be deployed to meet current MSHA standards. There are several scenarios to be considered, depending on mining methods (longwall, room and pillar), where outby workers perform their duties, and where caches should be located. The author will explain how CCERs should be deployed on working sections, on mobile equipment, for outby workers, and for outby caches. The presentation will also explain how cache locations should be determined to meet current MSHA standards. In addition, an update of CCERs approved under 42 CFR Part 84 Subpart O (mining) as of January 4, 2017 will be provided.

2:25 pm

Self-Contained Self-Rescuer Breathing Apparatus Improvement

J. Cornman, B. Toole and D. Gouletas; Diving and Life Support Systems Branch, Naval Surface Warfare Center Panama City Division, Panama City, FL

The Office of Mine Safety and Health Research with the Naval Surface Warfare Center Panama City Division are identifying and adopting technologies for improvement of a self-contained self-rescuer (SCSR) breathing apparatus for underground mine emergencies. This work expands the development of the Backpack Self-Contained Self-Rescuer (BSCSR) to increase user safety, minimize the wearable footprint, and provide for higher pressure oxygen service via a Valve Integrated Pressure Reducer (VIPR). The safety effort includes features that maximize lung isolation, enable speech transmission by using a half-mask oral/optical interface design and to facilitate apparatus switchover with integrated docking into the BSCSR T-bit component. Alterations to the scrubber, the counterlung, and outer soft shell improve the ergonomics and reduce the overall size of the BSCSR. Two VIPR prototypes were designed for increased oxygen service pressure and evaluated for performance in the BSCSR system. Continued work on the deployment and usability of the BSCSR harness system were completed to facilitate user acceptance. This presentation focuses on updating the project status and future design improvements.

2:45 pm

Technology Development for Closed-Circuit Self-Contained Breathing Apparatus

K. Coyne; Edgewood Chemical Biological Center, U.S. Army, Gunpowder, MD

The Respiratory Protection Branch is developing a four-hour closed-circuit self-contained breathing apparatus (CC-SCBA) for unique military operations. Existing CC-SCBA systems have technical and logistical limitations. The carbon dioxide (CO_2) sorbent generates significant heat, cannot be regenerated, and requires ice or re-freezable packs, increasing system weight and logistics. Oxygen (O_2) cylinders are filled to a high pressure to provide a long duration service life. Special equipment is required to safely handle and refill these high-pressure cylinders, increasing their cost and logistics. Current CC-SCBA do not have on-demand miniature blowers or breathing-air management systems to maintain proper O_2 and CO_2 levels. This paper discusses technology efforts to support a lower maintenance, reduced heat, lower profile, and lighter CC-SCBA. These include: 1) micro-electric miniature blower; 2) heat abating, humidity neutralizing technology CO_2 removal; 3) amine-based CO_2 removal; 4) membrane electrode assembly for CO_2 removal without heat generation; 5) micro-sensor array and controller for air temperature, humidity, CO_2, and O_2; and, 6) nano-material O_2 storage technology.

3:05 pm

Usability Study Plan on Closed-Circuit Mine Escape Respirators (CCMER)

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

NIOSH is developing Closed-Circuit Mine Escape Respirators (CCMER) as part of the research imperative of the MINER Act 2006. These devices are for self-escape by miners in an emergency. They are designed to be quickly deployable, incorporates masks and be able to be docked to a new unit without removing the mask, while exchanging units. Because these devices are to be on the miner while working underground, ergonomic factors were considered in the design to make them comfortable. This paper outlines elements of the study for verifying these ergonomic aspects. These are to check donning and operate the CCMER, switch from the first device to another, communicate and training needs. The human subjects will perform tasks in real mines; such as ability to deploy and don the first CCMER, talk with team members and switch to the second on a simulated escape route inside mines of different heights. Data collection by the investigators will be by direct observation, debriefing and analysis of questionnaires' after exercises. Data will be used to refine the CCMER designs ergonomically, address communication ability and assess training needs before production quality devices could be built.

3:25 pm

Novel Chemistries and Test Development for Mining Respiratory Protective Devices

D. Murray; NPPTL, NIOSH, Morgantown, WV

The Mine Improvement and New Emergency Response (MINER) Act, passed in 2006, listed respiratory protective device inadequacies noted after mining escape events, calling for new technologies that exhibit improved chemical performance in devices used in mines. NIOSH is invested in improving the chemical technologies built into these devices used in mines in two ways. First, testing procedures and systems which evaluate the performance of the chemical components under field conditions are being developed. This system incorporates elements that focus on evaluating chemical reactions and efficiencies in simulated breathing air. Current testing focuses on device duration or capacity but does not report criteria needed to effectively optimize chemical performance. Concurrently, novel framework and microporous materials are being evaluated that demonstrate superior performance in carbon monoxide oxidation, carbon dioxide absorption, and oxygen generation. In this presentation, the testing system will be described in detail, and an up-to-date review of the chemical screening results will be offered.

3:45 pm

New CCER Technology for Mines

R. Moran; Mine Survival, Inc., Panama City Beach, FL

With new CCER testing standards at NIOSH and new deployment standards at MSHA for Self-Contained Self-Rescuers used in underground coal mines, new technologies have emerged to enhance these emergency respirators from both ergonomic and cost perspectives. Mine Survival Inc. has taken decades of experience in Diving Technology and keen familiarity with new ISO standards to incorporate new design features into their Mine Survivor SCSR. By using the latest technology in CO2 scrubber materials and new cooling materials, the duration of the SCSR can be more than doubled as compared to previously designed respirators of similar size. This means the MSHA compliance requirements regarding the positioning and quantity of SCSRs in an underground coal mines can be adjusted to allow for fewer SCSRs in the mine. The packaging of the CO2 scrubber and the flow design of this respirator also create lower breathing resistance and lower breathing temperatures for the escapee. Other design features such as a “life vest” collar for quick donning and the ability to speak without exposure to Toxic breathing environs provide the user with safe and effective respiratory protection during emergency escape.

WEDNESDAY, FEBRUARY 22

AFTERNOON

2:00 pm **Room 102**

Coal & Energy: Coal Characterization to End Use

Chairs: *Z. Wang, FLSmidth Salt Lake City Inc, Midvale, UT*
S. Bhattacharya, Indian School of Mines

2:00 pm
Introduction

2:05 pm
Resource Quality Assessment of Northeast Indian High Sulfur Coals for Specific End Use

B. Saikia and T. Das; Polymer Petroleum and Coal Chemistry, CSIR-North East Institute of Science & Technology, Jorhat, Assam, India

The North-eastern region of India is endowed with a good reserve of about a billion tonnes of high sulphur Tertiary coals, widely distributed in the states of Assam, Meghalaya, Arunachal Pradesh and Nagaland. In this paper, the coal characterization and resource quality assessment of these high sulphur coals are presented aiming technological development in the country. This systematic detailed physico-chemical characterization will be use for promoting efficient and rational utilization of the available high sulfur coal resources in Northeast India in the domestic as well as industrial sectors. Advance level coal characterization including optical microscopy, FESEM, HRTEM, Raman, LTAXRD, ICPMS, Mossbauer spectroscopy, Ion chromatography, Fluorescence spectroscopy, Photoluminescence spectroscopy, Time of Flight Mass spectroscopy were carried out towards gainful utilization of these unique coals in the world. The chemical desulphurization processes in presence of ultrasonic and ionic liquids have removed sulphur contents substantially. Thermo-chemical processes also reduce sulphur contents leading to the formation high-value carbon products from these high sulphur coals.

2:25 pm
Revised Air Emissions Norms for Indian Coal Electricity Generation Plants: Compliance Strategies

T. DAS and A. Mukherjee; CSIR-CIMFR, Dhanbad, India

Future of electric power generation is under increasing pressure as environmental regulations become more stringent worldwide. The revised norms notified by the Indian Ministry of Environment, Forests and Climate Change in December 2015 have made the pollution standards more stringent for new coal-based power projects as well as old plants. The new standards are aimed at reducing air emissions of particulates, SO_x, NO_x and mercury to bring about an improvement in the ambient air quality in and around thermal power plants. Many existing plants could be overhauled to improve both efficiency and output while reducing particulate matter and mercury emissions.

Technically achievable and economically acceptable practices capable of reducing stack emissions include energy efficiency improvement measures, pre-combustion control measures (e.g., coal cleaning), optimizing existing air pollutants control devices. Retrofitting plants with new control technologies involves capital cost, which will ultimately raise the electricity cost. Legislations for pollutants such as particulates, SO_x and NO_x are likely to take priority over potentially more costly requirements set for mercury.

2:45 pm 17-094

Overview of Current US Longwall Gateroad Support Practices

M. Sears, G. Esterhuizen and I. Tulu; CDC/NIOSH, Pittsburgh, PA

In 2015, longwall mines provided nearly 60% of US underground coal production representing an increase from under 50% over the last 5 years. As a result of this increased production share, the percentage of ground fall related fatalities in longwall mines has increased compared to other mining methods. Additionally, the decline in non-injury roof falls appears to have stagnated over the past few years. To better understand current US longwall support practices, site visits were made to 11 mines over the past year. Additionally, including data collected from 10 mines within the last five years resulted in data from a total of 21 US longwall mines. This includes a broad range of geographic locations, geologic settings, ground conditions, and support designs. Two of the observed mines had options for cribless tailgates using cable bolts while the remaining mines used some form of standing support (cribs, posts, etc.). Standing support densities in the tailgate ranged from 0.05 MPa to 0.18 MPa and up to as much as 0.35 MPa in the #2 entry. Both entries averaged a support density of 0.12 MPa. This data provides a basis for research into improving gateroad support systems.

3:05 pm

Breakage and Washability Characterization of ROM Coal Using X-ray Computed Tomography

C. Lin[1], J. Miller[1], T. Nguyen[2] and A. Nguyen[2]; [1]Metallurgical Engineering, University of Utah, Salt Lake City, UT and [2]School of Chemical Engineering, University of Queensland, Brisbane, QLD, Australia

Characterization of run-of-mine coals is an integral part of the evaluation process, providing important information such as coal reserve size, the mining conditions, the coal quality and its washability characteristics. The most critical parameters for the efficient design of coal processing operations depend on the accurate prediction of coal breakage and washability characteristics of the coal resources. Since coal occurs as banded material, it is important to evaluate the breakage characteristics of coal based on rank, composition and texture. X-ray computed tomography (XCT) technology has been demonstrated to have the capability of analyzing washability and fragmentation parameters (particle size, energy, coal type). In this regard, progeny size distributions are obtained from sequential shatter drop tests (different input energy levels) and from XCT analysis. In this way, the breakage characteristics (selection and breakage functions) for coal particles can be established and prediction of particle size distribution (PSD) for different levels of energy input is demonstrated.

3:25 pm 17-025

Combustion Characteristics of Coal Blends

B. Nandi, S. Aich And S. Bhattacharya; Fuel & Mineral Engineering, Indian School Of Mines Dhanbad, Dhanbad, Jharkhand, India

Coal has been the most significant source of energy for India and would remain so at least for the next few decades. Indian coal is of drift origin and of high ash content (30-45%), most of it being Run-of-Mine coal. Most of the power plants in India source their coal from number of mines, most common being multiple sourcing. Usually coal from each source is burnt separately. For various reasons mostly associated with logistics, burning of blended coal is rarely practiced. A detailed investigation was therefore taken up to study in detail the combustion characteristics of six individual and their blends via non-isothermal thermogravimetric analysis at 800 ^{0}C by computing their kinetic parameters using Coats-Redfern integration method. A significant difference in terms of mass loss with temperature and activation energies have been observed between the kinetics of individual and blend samples, the latter showing better ignition performance and comprehensive combustion phase. It was also found that particles having the lowest percentages of volatile matter and ash could possibly be blended with particles having high ash and volatile matter to meet the required burning condition.

3:45 pm

Effect of Feed Characteristics on the Performance of Dense Medium Cyclones: a Literature Review

A. Anupam and S. Bhattacharya; Department of Fuel and Mineral Engineering, Indian School of Mines, Dhanbad, Jharkhand, India

The separation in a Dense Medium Cyclone (DMC) has been reported to be dependent on its geometry, operational parameters and medium properties. The properties of the feed coal particularly size and density distributions, have also been, in experience, found to influence the performance of DMCs. The separation efficiency reduces gradually, with decrease in size of feed coal at coarser sizes, and sharply at finer sizes. The presence of fine particles in the feed not only hampers the efficiency of a DMC, but also interferes with the recovery of medium, with moisture removal and increases the overall cost of the process – though the study in this regard has been limited. The distribution of feed coal in different density ranges, especially in the range ±0.1 of separation density, also appears to negatively influence the performance of the DMC. Despite, the significance of feed characteristics on DMC performance, they are generally ignored in industrial practice. This paper examines the available literature for correlating the performance of a DMC with the properties of the feed, medium and cyclone geometry. The performance of the DMCs vis-à-vis DMC manufacturers has also been reviewed.

WEDNESDAY, FEBRUARY 22

AFTERNOON

2:00 pm **Room 706**

Coal & Energy: Collegiate Mine Rescue

Chairs: *S. Chambliss, University of Kentucky Mine Rescue*
K. Pan, Virginia Tech, St. Clairsville, OH

2:00 pm

Introduction

2:05 pm

Collegiate Mine Rescue Organizations

K. Pan; Mining and Minerals Engineering, Virginia Tech, Blacksburg, VA

This presentations will cover the beginning of this technical sessions and the future plans for collegiate mine rescue organizations participation and collaboration. The efforts of this newly formed group will aid established and new organizations with skills and information to create a robust network of participants.

2:25 pm

Collegiate Mine Rescue: Building Better Habits for Now and the Future

S. Chambliss; University of Kentucky Mine Rescue, Henderson, KY

It can be completely upredictable when disasters and accidents will occur in the mining industry, and when those unique situations occur a local and state mine rescue team will be called upon to help isolate the problem and find a solution throughout the rescue process. It's the idea behind these mine rescue teams that are also behind those first responders in our communities: the risk of giving it all to save others and the sacrifice to rescue anyone in harm. When I was approached by our former SME President about the possibility of starting a mine rescue team locally at the University of Kentucky, I knew the opportunity to be a part of something extraordinary was knockng at the door. Growing up in a small mining community and having a father who has been captain of the Alliance Coal, Dotiki Mine Rescue Team for nearly two decades had exposed me to the practices of these teams and their encounters not only in rescue situations but also competitions as well. Mine Rescue Benefits: -Builds crucial industrial relationships -Instills sense of safety into everyday habits -Builds teamwork skills -Learn skills for the possibility of rescue situations.

2:45 pm

Virginia Tech Mine Rescue Team

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

I will speak about the running through of a practice both classroom training and field training. I will also talk about previous competitions that Virginia Tech Mine Rescue has participated in. I will talk some about the hopeful future plans for Virginia Tech Mine Rescue and how Mine Rescue has impacted the students on the team.

3:05 pm
The Use of a GoPro to Improve Collegiate Mine Rescue Training
S. Baker; Energy and Mineral Engineering, The Pennsylvania State University, State College, PA

Collegiate mine rescue teams face numerous challenges including inexperience, high turnover rates, and a lack of training facilities. The Penn State has found an innovative way to combat these challenges through the use of a GoPro camera to record their practices and competitions. This presentation will highlight how the team uses the footage to enhance their training and prepare new mine rescue members for competitions.

3:25 pm
Presentation of Collegitate Mine Rescue Awards - CSM
K. Pan; Anchor Longwall and Rebuild, Murray Energy Corporation, Wheeling, WV

The Colorado School of Mines will be presenting the awards for thier Bi-Annual Mine Rescue Emergency Development exercise.

WEDNESDAY, FEBRUARY 22
AFTERNOON

2:00 pm **Room 704**
Coal & Energy: Geologic Challenges in Underground and Surface Mining – Case Studies

Chairs: *S. Chatterjee, Michigan Technological University, Houghton, MI*
M. Peiravi, Southern Illinois University

2:00 pm
Introduction

2:05 pm
Longwall Induced Ground and Pipe Deformations at a Trona Mine – Case Study
G. Marino[2], A. Osouli[1] and M. Elgendy[2]; [1]Civil Engineering, Southern Illinois University Edwardsville, Edwardsville, IL and [2]Marino Engineering Associates,
St Louis, MO

Subsidence occurs after longwall mining. Projection of the vertical and horizontal displacement magnitude are necessary to evaluate damages to surface structures such as buried pipelines. In this study, the surface movement as a result of longwall mining of a trona mine is evaluated using empirical approach. Depth of the mine in the studied areas ranges from 460 m to 520

m. The chain pillars length and width were 60 m and 30 m, respectively. The width of longwall panels varied from 150 m to 240 m. The collected subsidence data were analyzed to identify mining induced deformations. The adverse vertical and horizontal movements were considered in analyzing the performance of the buried pipelines present at the site. It was determined that the rate of movement at shallow depths can be up to 0.004 in/min. The effect of this movement rate on creation of undesirable frictional stresses around buried pipelines, which some of them are old, is discussed. Finally, the results of a series of pipe jack tests conducted at the site is presented and discussed.

2:25 pm

Stochastic Finite Difference Simulation of Laboratory Compressive Tests

D. Gao[1], B. Mishra[2] And Y. Xue[3]; [1]danqinggao@outlook.com, Morgantown, WV; [2]brijes.mishra@mail.wvu.edu, Morgantown, WV and [3]yuting.xue1988@gmail.com, Morgantown, WV

Heterogeneity and discontinuity significantly affects the strength of the intact rock and rock mass. For accurate stability prediction, it is imperative that the laboratory behavior is included in the rock mass behavior. However, past research largely used arbitrary scaling approach to produce rock mass strength. In this paper, we propose a stochastic approach for determining the rockmass strengths. The laboratory data is treated to fit the extreme value distribution model. MATLAB with the extreme value model is used for developing a database for each physico-mechanical property. The rock material database is finally used to develop the rock model in FLAC and FLAC3D. Two and three dimension model results show that the peak value of stochastic model is significantly lower than the average valued model. In addition, the failure mode is also influenced by the randomness density of material database. The results highlight the importance of stochastic analysis in rock failure prediction.

2:45 pm 17-093

Overburden Strata Deformation Monitoring Based on Distributed Optical Fiber Sensing: Novel Method for Ground Control

J. Chai[1], Q. Yuan[1], D. ZHANG[1], Q. Biao[2], J. Liu[1] and Y. Li[1]; [1]Energy School, Xi'an University of Science and Technology, Xi'an, Shannxi, China and [2]Agapito Associates Inc., Grand Junction, CO

Overburden strata deformation monitoring is one of the key problems in ground control. Using geophysical method through surface drilling to detect strata deformation is commonly used in the industry. In this paper, a geophysical method based on the distributed optical fiber sensing (DOFS) system were conducted in the laboratory, where a DOFS-based strata deformation monitoring experiment was performed with three physical models. The results show that the DOFS method precisely detects the rock mass deformation and strata structure forming with the Brillouin frequency shifts (BFS) representation. The BFS curves are divided into three phases, which reflects the horizontal three zones developed in the overburden. The BFS distribution presents a multiple stages form, the 1st stage corresponds to the caving zone and the 2nd stage corresponds to the fracture zone. Based on the multiple stages form, the evolution of the water flowing through fractured zone have been determined and the controlling effect of key strata over the water flowing fracture has been pointed out. In the end, the comparison validation proves the accuracy and reliability of this method, it could be a new way for ground control.

3:05 pm 17-090
Stability Assessment of Main and Tail Gate of a Modified Longwall Mining Operation by Numerical Modeling

M. Emad[1] and M. Khan[2]; [1]Mining Engineering Department, University of Engineering & Technology, Lahore Pakistan, Lahore, Pakistan and [2]Mining & Nuclear Engineering Department, Missouri University of Science & Technology, Rolla, MO

Coal mines opting for longwall mining or its variations mostly rely on the main and tail gates for their production. Stability of these entries or cross-cuts is crucial in coal mining operations. Roof or strata failure can be fatal, may lead to property loss and delay in production. Failure of gates depends upon many factors including the mining method, panel dimensions, pillar width, mine depth, caving speed and roof strength properties. In Pakistan coal is mined through a variation of longwall mining method with almost no mechanization while using timber as a primary support. Timber support as choke is very useful in coal mines especially in overhanging face. Similarly gate entries are supported by choke supports throughout their length. In this paper the stability of the longwall gate is assessed for a typical coal mine in Pakistan by using finite element code. It is shown that the elas-to-plastic analysis is essential for assessing the stability of a gate entry. A model parametric study is performed for some factors. The results showed that the existing mining practice is not suitable and there is a need to review the mining approach.

3:25 pm 17-130
Manual P-Phase Picking on Noisy Microseismic Data

C. Mborah; Mining & Nuclear Engineering, Missouri University of Science & Technology, Rolla, MO

The acoustic emission/microseismic monitoring (AE/MS) technique has widely been used in the mining environment for monitoring rock mass stability. Successful implementation is hinged on accurately determining the P- or S-wave arrivals used in the determination of the source of event. Determination of the arrival phase is usually performed visually. The mining environment is characterized by high noise levels and of intensities. Performing manual phase picking on this data can sometimes be tedious and time consuming if not impossible. In this paper, a proposal for improving manual P-wave phase arrival picks is discussed. The method involves the filtering of the AE/MS data using a stationary discrete wavelet transform method and the computation of the signal power and the root mean square (RMS). The preliminary P-phase arrival time is picked using the results of the calculated power and RMS values respectively. The two results are then superimposed on each other to determine the final pick. The method is validated using AE/MS data from two datasets obtained from two separate underground mines. The results of the study showed that the picking method is reliable and robust.

3:45 pm
Coal Seam Thickness Modeling Under Geological Uncertainty: a Multiple Point Simulation Approach

S. Chatterjee[1], A. Paithankar[1] and A. Kumar[2]; [1]Department of Geological and Mining Engineering and Sciences, Michigan Technological University, Houghton, MI and [2]McGill University, Montréal, QC, Canada

Coal seam thickness modeling is a crucial task for understanding the coal volume within a deposit. Tradition practices use different CAD-based software to digitize the coal seam or seams from the exploration drilling. These techniques generally work well when the geology of the deposit is very simple. However, they may either over- or under-estimates the coal volume for geologically complex deposit. The proposed paper deals with the uncertainty of the coal seam thickness as well as coal volume using multiple point geosatistical simulation approach. In this approach, the CAD-based coal seam model was anchor with the exploration drilling data using Bayesian analysis. This method will allow us to evaluate the uncertainty of the coal volume and tonnage. The proposed method was applied in a coal mine from India to show the effectiveness of this technique.

4:05 pm 17-051

Effects of Longwall-Induced Subsurface Deformations on the Mechanical Integrity of Shale Gas Wells Drilled Over a Longwall Abutment Pillar

W. Su; Ground Control Branch, National Institute for Occupational Safety and Health, Pittsburgh, PA

ABSTRACT This paper presents the results of a comprehensive study on the effects of longwall-induced subsurface deformations on the mechanical integrity of shale gas wells drilled over a longwall abutment pillar. The primary objective is to demonstrate that a properly constructed gas well in a standard longwall abutment pillar can maintain mechanical integrity during and after mining operations. A study site was selected over a southwestern Pennsylvania coal mine, where an array of surface, subsurface, and underground instrumentation was installed and monitored. Prior to the longwall extractions, a number of 3D finite element simulations were conducted. Comparisons of the 3D finite element simulations and the instrumentation results indicate that measured subsurface deformations, surface subsidence and pillar pressure are in good agreement with those predicted by the 3D models. This research represents a very important step and initiative to utilize the knowledge and science obtained from mining research to improve miner and public safety as well as the safety and health of the oil and gas industries.

WEDNESDAY, FEBRUARY 22

AFTERNOON

2:00 pm **Room 702**

Coal & Energy: Research and Development II

Chairs: *M. Trevits, Xtraction Science and Technology, Inc, Pittsburgh, PA*
L. Chen, Henan Polytechnic University, Henan, China

2:00 pm
Introduction

2:05 pm 17-065
Fiber Reinforced Ultra Rapid Hardening Sprayed Concrete for Mining and Civil Applications

S. Tadolini and P. Mills; Minova, Georgetown, KY

This research produced a shotcrete formulation with structural strength within a few minutes to prevent parasitic loading and allow ingress into damaged structures within a few minutes of the mix formulation being applied. This also applies to mining conditions where rapid support of progressive failures can minimize failure. An additional benefit was the discovery that the product had extremely high adhesion properties in addition to high flexural strengths. The approach to product design was the development of “single bag” dry mixes that are entirely self-contained, can be rapidly transported anywhere in the field or underground, and be deployed using simple equipment. A commercial version of this material is currently offered as Minova’s Tekcrete Fast® product which has been successfully deployed in the mining industry and is currently being used in civil, construction and tunneling operations. The material can rapidly stabilize unstable ground in metal/nonmetal and coal mines. This paper described the technology development, product testing results and applications in mining and civil applications.

2:25 pm
Effects of Dewatering Flooded Abandoned Room and Pillar Mines on Surface Subsidence

Y. Luo and J. Yang; Mining Engineering, West Virginia University, Morgantown, WV

Many factors can induce surface subsidence events over abandoned underground room and pillar mines. Frequently, mine water plays an important role in causing such subsidence events. However, mine water could also serve the purpose to prevent subsidence. Dewatering abandoned room and pillar mines have been identified as the main cause of a number serious mine subsidence events in the past. In this paper, the mechanism for mine water to prevent surface subsidence over abandoned room and pillar coal mines havs been studied. A mathematical model has been proposed to quantify the potential effects of mine water on the structural stability of mine pillars, roof and floor as well as the potential for causing surface subsidence. The model will be validated with actual cases.

2:45 pm
Thermal Insulating Shotcrete: Experimental Synthesis

P. Rao, K. Muralidharan and M. Momayez; Mining and Geological Engineering, University of Arizona, Tucson, AZ

Geothermal heat in deep underground workings is a significant risk to the health and safety of miners. The primary objective of this research is to limit heat liberation by the use of a cost effective sprayable insulation. The material is synthesized from constituents rich in silica and alumina such as mine tailings. In a preliminary study, the material was produced from pristine element such as alumina and silica to form a 3D network of structures known as geopolymers possessing an amorphous character. These 3D networks were activated using NaOH, a strong base. Furthermore, the effect of Si:Al ratios along with the effects of temperature and curing time on the final structure were studied. Likewise, geopolymer foams were produced using sodium bicarbonate as a chemical foaming agent. Compression tests were carried out to study the ability of this material to withstand mechanical load. To evaluate the effectiveness of insulation, thermal conductivity experiments were performed. To incorporate moisture stability and enhance the mechanical strength, composite structures were made by using graphene-oxide as a filler material and tested for compressive strength and thermal behavior.

3:05 pm

Subsurface Mine Ventilation Research

J. Lee[1], H. Mischo[2], J. Brune[1] and J. Weyer[2]; [1]Colorado School of Mines, Greeley, CO and [2]TU Bergakademie Freiberg, Freiberg, Germany

Optimization of ventilation systems plays a huge role in saving a company valuable time, money, and energy. At the experimental mine at TU Bergakademie Freiberg in Germany, a full scale, ductwork ventilation lab was constructed to analyze the impact that different types and sizes of ducts have on ventilation systems. The lab consists of over 300 meters of duct work. Each 50-meter segment consists of flat or spiral ducts that differ in size ranging from 400-600mm. 150 meters of the system is comprised of properly installed new ducts, and the other 150-meters are poorly installed, and old. Both ducts are attached to a forcing radial fan that has the ability to direct the airflow into either portion of ducting. Ports are installed to record airflow velocities and pressures for each segment. Testing included measurements of static, dynamic, and total pressure at twelve points along the system. A pitot tube and manometer were used to take these measurements. Calculations were made to determine flow velocity, volume flow, duct resistance, leakage, and the shock loss effects around bends and elbows. Information from these tests will be useful in optimizing ventilation systems.

3:25 pm

Discrete Modeling of Radon Gas Migration through the Fractured Zones in Caving Mines

K. Ajayi[1], P. Tukkaraja[2], K. Shahbazi[1], K. Katzenstein[3] and D. Loring[4]; [1]Mechanical Engineering, South Dakota school of mines and Technology, Rapid city, SD; [2]Mining Engineering & Management, South Dakota school of mines and technology, Rapid city, SD; [3]Geology and Geological Engineering, South Dakota school of mines and technology, Rapid city, SD and [4]Climax Molybdenum Co., Empire, CO

A number of large bulk-scale underground ore bodies contain at least trace of uranium mineralization. Bulk extraction of these orebodies using cave mining methods involves undercutting the orebody. This facilitates the mechanism of gravity naturally breaking the rock during the cave development process. The fractured zone developed during the developing stage of the cave contributes to radon gas emission if pressure and/or concentration gradients exist between the cave environments. This study develops a discrete fracture network (DFN) model to predict radon emission from the fractures zones by considering the radon transport through the DFN due to advection and diffusion. Results from this study predict macroscopic coefficients such as permeability and effective diffusivity.

3:45 pm

An Investigation of the Impact of a Large Steel Plate on the Magnetic Field Distribution of a Magnetic Proximity Detection System

J. Li, J. DuCarme, M. Reyes and A. Smith; The National Institute for Occupational Safety and Health, Pittsburgh, PA

Magnetic proximity detection systems are mounted on mobile mining machines to prevent underground workers from being pinned or struck by machine motion. The system generates magnetic fields around the machine to determine safe working distance around the machine. The worker worn magnetic sensor measures the magnetic field to determine relative worker location. Large masses of steel, such as those from mining equipment, can alter the magnetic field distribution. This affects the locational accuracy of the system thus adversely impacting workers safety. NIOSH researchers developed a method and test system to conduct a study that investigates the impact of a steel mass on the magnetic field distribution. The results show that a large steel plate can strengthen the magnetic field perpendicular to the generator by up to 40%. Furthermore, they show that the degree of the influence on the field distribution is a function of distance. The results from this study can be used to further develop and improve the performance of electromagnetic proximity detection systems used in underground mining applications.

WEDNESDAY, FEBRUARY 22

AFTERNOON

2:00 pm **Room 711**

Coal & Energy: Ventilation Innovations

Chairs: *P. Tukkaraja, South Dakota School of Mines and Technology, Rapid City, SD*
S. Dereski, Barrick Goldstrike, Elko, NV

2:00 pm
Introduction

2:05 pm **17-046**
Dynamic Seals: a Way to Prevent Longwall Gob Explosions

J. Brune and S. Saki; Colorado School of Mines, Golden, CO

Abstract Most, if not all longwall gob areas accumulate explosive methane-air mixtures that pose a deadly hazard to miners. Numerous mine explosions have originated from explosive gas zones (EGZs) in the longwall gob, including the 2010 explosion at the Upper Big Branch mine in the US State of West Virginia that fatally injured 29 miners. Research at the Colorado School of Mines (CSM) have studied EGZ formation under projects funded by the National Institute for Occupational Safety and Health. They found that EGZs form along the fringe areas between the methane-rich atmospheres deep within the gob and the fresh air ventilated areas along the working face. Researchers found that, for progressively sealed gobs, a targeted injection of nitrogen from the headgate and tailgate, along with a back return ventilation arrangement, will create a dynamic seal of nitrogen that effectively separates the methane zone from the face air and eliminates the EGZs.

2:25 pm **17-111**
Development of a Smart Monitoring and Control System Test Apparatus

K. Raj, R. Jacksha, C. Sunderman and C. Pritchard; SMRD, CDC/NIOSH, Spokane, WA

In underground mines, repeated short-term exposure to high levels of airborne contaminants can become a serious health issue. Currently there are no common mechanisms to control or mitigate these localized short-term high exposures of contaminants. To improve miners' health and safety, the

National Institute for Occupational Safety and Health (NIOSH) Spokane Mining Research Division (SMRD) is developing a Smart Monitoring and Control (SMAC) system for real-time monitoring of mine air quality with integrated counter-measures to reduce these high concentrations of airborne contaminates in localized sections of mines. To develop and test a SMAC system that could be implemented in an underground mine, researchers at SMRD built a test apparatus incorporating a fan, louver, ducting, and monitors combined with atmospheric monitoring and control software to institute effective countermeasures to reduce contaminant levels.

2:45 pm

A 2016 Case Study in Primary Ventilation Circuit Optimization: How to Make Changes and Influence Philosophy

A. Powell[1], A. Rai[3] and T. weatherwax[2]; [1]Mine Engineer, Winnemucca, NV; [2]Technical Services Superintendent, Winnemucca, NV and [3]Chief Engineer, Winnemucca, NV

Mine design work from a long term perspective (2-10 years) is often a complex and daunting task with many moving parts and economic concerns. One of the basic concerns that can easily become neglected is the vision behind the primary ventilation circuit of the mine and the steps needed to integrate it with the life of mine designs from the outset rather than as an afterthought. The paper will outline a case study of how one active underground mine is striving to make this change. Topics covered include a summary of historical primary circuit iterations with a discussion of associated strengths and weaknesses, recent and forthcoming updates to the ventilation infrastructure with insight on the shift in circuit design goals, and the future ventilation philosophy being considered and implemented.

3:05 pm **17-137**

Tracer Gas Study to Determine Face Ventilation Air and Gob Gas Movement Patterns on a Bleederless Longwall Panel

S. Schatzel, V. Gangrade, C. Hollerich, J. Addis and L. Chasko; National Institute for Occupational Safety and Health, Pittsburgh, PA

A ventilation study using tracer gas was conducted at a western US coal mine. The objective of the study was to evaluate the leakage of longwall face air off the face and into gob and to document the presence or absence of face air leakage pathways. The operator uses a bleederless ventilation system and blowing ventilation air throughout the mine. The study was conducted on active panel and included both underground and surface monitoring sites. The study used sulfur hexafluoride (SF6) released as a slug in tests conducted on the face and in the front of the gob inby the face. The transport rate of SF6 in the gob was measured to be about 1 to 2 ft/min. A separate tracer gas test initiated with the release of SF6 in to the legs of the first shield showed the existence of more than one pathway of face air in the general direction of the headgate towards tailgate corner. The face test supports the concept of an airflow path within the shield legs or behind the shields in addition to the main airflow on the face. A detailed characterization of air and gas movement allows a mine to better asses their ventilation design and its adequacy in controlling gas on the face and in the gob.

3:25 pm
Sound Level Surveys around Auxiliary Fans in Underground Coal Mines
F. Calizaya; Mining, University of Utah, Salt Lake City, UT

In underground coal mines, working areas can be filled with extensive and damaging noise. The sources include continuous miners, roof bolters and ventilation fans. When underground fans are used, the noise levels are usually above the Permissible Exposure Limit. If the fans are not equipped with silencers, the sound levels can be greater than 110 dB(A). This study summarizes the results of sound level measurements and fan performance tests carried out at and around three auxiliary ventilation systems in underground coal mines located in the western US. In each mine, high pressure fans installed in rigid ducts and equipped with silencers are used to ventilate development headings and to discharge the contaminated air to the main return. Sound pressure levels monitored at the fan installations are reported, the resulting noise spectra analyzed, and ways to minimize noise induced hearing loss by improved mining layouts and efficient auxiliary ventilation systems are addressed.

3:45 pm 17-048
Effect of Simulated Longwall Coal Mine Gob Conditions on the Burning Velocity of Premixed Methane-Air Combustion
C. Strebinger[1], m. fig[1], K. Blackketter[2], A. Walz[2], G. Bogin[1], J. Brune[1] and J. Grubb[1]; [1]Colorado School of Mines, Golden, CO and [2]Red Rocks Community College, Lakewood, CO

Longwall coal mine explosions can be disastrous as evidenced by the Upper Big Branch Mine explosion in 2010 which resulted in 29 casualties. Methane explosions in the gob are not well understood and thus there is a need to fundamentally understand flame dynamics in rock rubble. The impact of simulated gob conditions on methane gas ignition and flame propagation was investigated in horizontal cylindrical tubes packed with rock rubble. Experiments show burning velocity is sensitive to ignition location and simulated gob conditions (e.g. packing orientation and density, and thermal properties). More densely packed gob areas reduce burning velocities when placed upstream of the ignition source, but increase burning velocities if located downstream of the ignition source due to the increase in exhaust pressure accelerating the flame. In contrast, a loosely packed gob area results in the opposite effect on the burning velocities for the same orientation of the ignition source. These results demonstrate that methane gas explosions in a longwall gob require a fundamental understanding of the complex interaction of fluid dynamics, heat transfer, and flame dynamics.

4:05 pm
Identifying and Quantifying Major Heat Sources in Underground Mines using a Continuous Climatic Monitoring System
L. O'Connor, P. Roghanchi and K. Kocsis; Mining Engineering, University of Nevada, Reno, Reno, NV

To understand and model heat and humidity transport, all major heat sources in an underground mine need to be identified and accurately quantified. There can be a considerable difference in the spectrum of the heat and mine power source distributions between different mines due to many factors such as depth, the virgin rock temperature (VRT), the level of mechanization, power sources, geothermal activity and rock thermal properties. This paper aims to discuss an approach to quantify heat loads from different

heat sources at a gold mine in Nevada using a continuous climatic monitoring system. During this project, twelve multi-channel data loggers were installed in both primary and auxiliary ventilation systems in order to identify and quantify the heat sources, including heat generated by auxiliary fans and mining equipment. In this paper, we will highlight the advantages and challenges in identifying and quantifying heat sources in an underground mine when continuous monitoring systems are used. We will demonstrate that the contribution of heat sources to the overall heat load is highly dependent upon the atmospheric temperature and can vary daily and seasonally.

WEDNESDAY, FEBRUARY 22

AFTERNOON

2:00 pm **Room 612**

Health & Safety: International Perspectives on Mine Safety and Health

Chairs: *E. Clausen, TU Clausthal, Clausthal-Zellerfeld, Germany*
J. Brune, Colorado School of Mines, Golden, CO

2:00 pm
Introduction

2:05 pm 17-099
Project Optimization and Competitiveness Enhancement Through an Integrated Health and Safety Management

J. Herhold[1], H. Mischo[1] and S. Plaum[2]; [1]TU Bergakademie, Freiberg, Sachsen, Germany and [2]Hochschule RheinMain, Wiesbaden, Germany

Current and future operational processes in the mining and underground construction sector are under the influence of the prevalent competition and the acute necessity of optimization approaches concerning corporate and project processes. Besides general construction procedures, especially underground construction procedures and procedures in the field of deep shaft construction are high-profile. Those processes describe high technical challenges as well as increased requirements to occupational safety and health. Therefor an occupational safety management, which should be adjustable to the company itself and adaptable to all kinds of projects, shall be created. The creation of such an occupational safety management would lead to an economically optimized and safe (within the scope of OSH law) implementation of internal activities for the performance of construction services underground and in the field of deep shaft construction. With this approach the satisfaction of the high safety request as well as the demand for process optimization, as part of keeping the own competitiveness, will be satisfied successfully at once.

2:25 pm

Taking 'the ICMM Critical Control Management Guide' into the Field. Case Study - Barrick Gold 'Life Saving Controls'

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

The International Council on Mining & Metals (ICMM) developed a set of guidance documents around fatal risk in collaboration with 23 global mining council member organizations. The intent was to provide a process the international mining industry could follow to design thier own internal standard for engaging miners, identifing fatal risks and drive leaders to implement and check critical controls. Step 8 - Verification and Reporting is one of the most challenging elements of this process. Mining Executives are required to initiate the design and implementation of an efficient and transparent system for ensuring competent leaders get out into the field and physically check controls are in place and remain effective. Barrick Gold executed a rigorous process to identify and select appropriate controls. RUT LLC then partnered with Barrick to implement an efficient field based checking and reporting system to drive compliance for what Barrick refer to as 'Life Saving Controls'. The crystal clear visibility of controls compliance has helped drive the closure of gaps and provide confidence to senior leaders that those controls are in place and effective in managing fatal risk.

2:45 pm

Incorporating Public Health and Epidemiological Interventions that Promote Community Development and Buy-in for Mining Projects

M. Jewell; Burns, Figa & Will, P.C., Greenwood Village, CO

Successful international mining projects incorporate effective and sustaining public health interventions. However, the proper and efficacious implementation and management of community-based public health programs demands a keen understanding of the legal, scientific, and practical challenges presented by these endeavors. This issue is important given the increased development of hard rock ventures in politically and culturally sensitive arenas. Securing community buy-in through programs facilitated by Operators that increase positive public health outcomes can not only streamline relationships with culturally-sensitive communities, NGOs, and foreign governments, but they can also deliver interventions that improve morbidity and mortality in underserved regions. This leads to attractive value-added for Operators looking to secure additional investment through its more comprehensive use of health data. This paper will highlight how to create, structure, and maintain public health interventions. Additional emphasis will center on cost-effective monitoring and evaluation that help Operators use statistical drivers to promote Operators' investment procuring efforts.

3:05 pm

Using Sound Public Health Science to Promote Mining Projects

M. Jewell; Burns, Figa & Will, P.C., Greenwood Village, CO

Successful resource development projects must incorporate an effective approach to communicating real and perceived public health externalities of domestic and international mining development. This paper presents a fundamental introduction to public health science and the use of data to promote resource development projects. It also provides a primer to creating, structuring, and maintaining public health interventions, and offers data-driven anecdotes. Readers and attendees can expect to increase their knowledge in basic public health and epidemiology applied in resource extraction contexts. Attendees will further understand that socio-public health needs in resource development contexts extend beyond traditional infectious disease, nutrition, and primary care paradigms. This presentation equips mine managers, engineers, decision-makers, and any person interested in: Cutting through what popular studies in the media really mean to mining companies; Unravelling scientific and medical jargon; Learning about how increased access to reliable and inexpensive resources is not only good for the public's health, but it has also been one of the greatest public health achievements in history.

3:25 pm

International Trend of Lower NO2 Exposure Limits Under Consideration of Current Detection Technology

Christoph Feyerabend, Drager Safety AG & Co KGaA, Lubeck, Germany

For several years occupational exposure limits for NO2 have been under discussion leading to dramatically lower exposure limits in several jurisdictions in recent years. Following the recommendation of the American Conference of Governmental Hygienists for a lower NO2 threshold limit value, several provinces in Canada have adopted this value. The European Union has issued a new recommendation as well, which is now being implemented in member states. This especially affects mine operators due to the combination of blasting and diesel emissions. The presentation will focus on these developments as well as currently available detection technique and the challenges involved to monitor NO2 at the new exposure limits.

WEDNESDAY, FEBRUARY 22

AFTERNOON

2:00 pm **Room 610**

Health & Safety: Open Forum for the Future of the Nation's Mining Safety and Health Research Agenda

Chairs: *L. Saperstein, Missouri University of Science and Technology, Nantucket, MA*
E. Lutz, NIOSH, Spokane, WA

2:00 pm

Introduction

2:05 pm

Forum on the Future of the Nation's Mining Safety and Health Research Agenda

E. Lutz[2] and L. Saperstein[1]; [1]Mining Engineering, Missouri University of Science and Technology, Nantucket, MA and [2]Spokane Mining Research Division, NIOSH, Spokane, WA

The NORA National Mining Agenda has 8 Objectives and 263 sub-objectives for research that improves the Health & Safety of miners. With a goal of opening up this agenda to the broader mining community, a panel of experts drawn from industry, academia, labor, and government will discuss current as well as emerging mine worker H&S trends. Audience responses will be solicited. Recent, rapid, cyclical changes in demand for energy, metallics, and non-metallics may have new and substantial H&S challenges. Depressed demand may create as many H&S problems as an uncontrolled boom. What are the existing unsolved problems and what new ones are predicted? What H&S technologies should be developed in our quest for zero fatalities for workers in tomorrow's increasingly mechanized mines? Who will be tomorrow's mine workers and how will they be trained so as to be safe as well as productive? The panel's responses will be collected and archived on the NORA web site. Panelists are Dr. J. Burgess, U of AZ, Mark Ellis, IMA-NA, George Gardner, MSHA Pitt Center, Stacy Kramer, Freeport-McMoran, Dr. George Luxbacher, MELM Consulting, Dr. Hugh Miller, CSM, Josh Roberts, UMWA, and David Snyder, NIOSH-NORA.

WEDNESDAY, FEBRUARY 22

AFTERNOON

2:00 pm **Room 110**

Industrial Minerals & Aggregates: Special Topics

Chairs: *R. Raitani, Solvay America, Stamford, CT*
B. Wang, ingevity

2:00 pm

Introduction

2:05 pm

Salt Mine Journey to a Truly Continuous Mining and Haulage System

B. Ziegler; Joy Global, Franklin, PA

As conventional drill and blast methods continue to be used in many salt mines, a case study will be presented on a Canadian's salt mine's journey to a truly continuous mining and haulage system. This presentation will include real-world results, demonstrating how the introduction of heavy duty continuous miners and the latest flexible continuous haulage, the "flexible conveyor trains" (FCTs), are on target to deliver a 20% increase in production and a 20% reduction in the cost-per-ton, over a three-year period. As the system lends itself to automation, the presentation will also cover the latest advancements in system automation, including automated sump and shear cycles and collision avoidance.

2:25 pm

Wisconsin Nonmetallic Mining Operations – the Revised General Strom Water Permit

A. Martin and M. Nimmer; Mining, Foth Infrastructure & Environment, LLC, De Pere, WI

Like most states, Wisconsin has sand and rock quarries supplying materials for construction, agriculture, and manufacturing. The state is also blessed with excellent frac sands, which has fueled a booming sand mining industry.

Upcoming revisions to the general storm water permit separate aggregate and sand operations from the more complex industrial frac sand operations. This presentation will discuss the new general permit requirements. Operators will need to improve their understanding of process water flows, hydrology, and drainage of their facilities. The state will be forming a committee to evaluate the geochemistry of industrial sand facilities using the required extended analytical data mandated in the permits. We will discuss this and other operational and compliance challenges. Facilities will benefit from being proactive with several tight timelines. There are also opportunities that may bring value to the operation including structural and work practice modifications. In tight economic times, the new permit increases the pressure on these operations to remain viable.

2:45 pm

Media Stability Issues with Dense Medium Separators

P. Jain and S. Bhattacharya; Department of Fuel and Mineral Engineering, Indian School of Mines, Dhanbad, Dhanbad, Jharkhand, India

Heavy medium separation is a special case of gravity concentration in which a heavy media of specific gravity between the heavier mineral and lighter mineral is used. The effective separation depends on the various factors such as concentration criterion, liberation, stability of media, type of separator, etc. Stability of suspension is very important requirement for efficient separation of minerals and coals in close specific gravity range. Slight change in the density of the media can lead to inefficiencies resulting in poor separation of heavy material from the lighter ones thus degrading the grade of the final product. Preparation of ultralow-ash coal needs two stage similar density separations, it is necessary to reduce the suspension condense in cyclone. Factors which affect suspension condense include: centrifugal factor, suspension concentration, the density and size of heavy media. Present paper aims at covering various factors affecting the stability of suspensions, issues related to magnetite media, ferrosilicon and other mediums. Various methods adopted at industry for maintaining the suspension stable.

3:05 pm

Orfom® D8 Depressant in Copper/Molybdenum Separation Operations

B. Ramos and C. Brown; Mining Chemicals, Chevron Phillips Chemical Company, The Woodlands, TX

Most Cu/Mo separation operations are conducted by using inorganic NaSH as the copper sulfide depressant. While NaSH provides appropriate performance for such operations, it does exhibit several undesirable qualities including hazardous gas evolution, repulsive odor, and can require high consumption rates for effective copper sulfide depression. An organic reagent developed and marketed by Chevron Phillips Chemical Company LP as Orfom® D8 Depressant, provides a commercial solution as a full NaSH replacement in Cu/Mo separation operations. Orfom® D8 Depressant achieves high Mo grade without being controlled by ORP while providing significantly improved handling, safety and storage profile, lower treatment rates, and does not require inert (nitrogen) gas. This paper will provide case study data from laboratory and plant scale trials. Discussions will include data on process variables including dosage, retention time, addition points, and pH when using Orfom® D8 Depressant as a full NaSH replacement.

WEDNESDAY, FEBRUARY 22

AFTERNOON

2:00 pm **Room 505**

Mining & Exploration: Geology: Mining Geochemistry

Chairs: *D. Levitan, Barr Engineering, Minneapolis, MN*
T. Diedrich, MineraLogic LLC, Duluth, MN

2:00 pm

Introduction

2:05 pm

Evaluating the Hydrothermal Fluid History of the Marigold Deposit, Nevada Using (U-Th)/He Thermochronology

D. Huff[1], E. Holley[2] and W. Guenthner[3]; [1]Geology and Geological Engineering, Colorado School of Mines, Golden, CO; [2]Mining Engineering, Colorado School of Mines, Golden, CO and [3]Geology, University of Illinois at Urbana-Champaign, Champaign, IL

Despite the history of production from Carlin-type gold deposits (CTGDs), researchers continue to debate the source of the parent fluids. Au mineralization at Marigold is concentrated along faults and along the altered margins of Cretaceous dikes. To determine the age of the most recent hydrothermal fluid flow, apatite aliquots from two dikes were submitted for (U-Th)/He thermochronology dating. The calculated ages were Eocene (39.9 ± 0.3 Ma and 41.9 ± 0.3 Ma). Although Eocene magmatism has not been recognized at Marigold, five Eocene intrusions have been dated 8 km to the north. Eocene cooling ages support the hypothesis that local Eocene magmatism produced the hydrothermal fluids responsible for CTGDs. This research also investigates Fe-oxide (U-Th)/He thermochronology as a possible exploration tool. Jasperoids can be spatially associated with Au mineralization in CTGDs, but they can also be barren and are an unreliable indicator. We hypothesize that jasperoids associated with Au formed from Eocene fluids, whereas barren jasperoids formed at different times. Petrographic/geochemical characterizations of Fe-oxides and preliminary results from (U-Th)/He analysis are presented here.

2:25 pm

Zircon Trace-Element Composition as an Indicator of Porphyry Mineralization

I. Barton[1], R. Stegen[2] and M. Barton[1]; [1]UA Lowell Institute for Mineral Resources, Tucson, AZ and [2]Freeport-McMoRan Copper & Gold, Tucson, AZ

Zircon trace-element composition has been suggested as a prospecting tool. Magma oxidation associated with evolution of a metal-bearing, SO_2-rich fluid transforms Ce^{3+} and Eu^{2+} into Ce^{4+} and Eu^{3+}, both of which are relatively compatible in zircon. Thus, magmas that exsolve an ore-forming fluid would presumably crystallize zircons with larger Ce anomalies (Ce/Ce*) and smaller Eu anomalies (Eu/Eu*) than are observed in zircons from less prospective intrusions. We performed 536 LA-ICP-MS analyses of trace elements in zircons from 24 intrusions at Morenci, Tyrone, and Safford, three large Laramide porphyry Cu districts in the U.S. Southwest. The results indicate that zircons from mineralized intrusions have larger Ce and smaller Eu anomalies than zircons from barren intrusions, consistent with predictions. However, the magnitude of the difference between barren and mineralized zircons varies from district to district. No single zircon from Morenci or Safford meets the "prospectivity threshold" of Ce/Ce*>70 and Eu/Eu*>0.4 outlined in the literature. This indicates that no single set of numbers can be applied universally to evaluate mineralizing potential in all porphyry districts.

2:45 pm

Exploration Databases: Avoiding Common Pitfalls in Data Collection to Maximize the Impact of Geologic Observations for Resource Estimation and Geometallurgical Modelling

T. Matthews; Geology, Gustavson Associates, Lakewood, CO

The transition from analog to digital data capture in exploration has changed the way we aggregate geologic observations and geochemical data. Some commonly used practices in exploration data capture and database design significantly interfere with the eventual utility of the data collected. Among the more common issues are treating alteration information as a discrete variable in data collection, incomplete recording of relative intensity of alteration, and incomplete sample location data. The objective of this paper is to explore ways to address data collection and data capture which will render geological observations as useful as possible in geological modelling, resource estimation, and geometallurgical modelling processes.

3:05 pm

Optimizing Active and Secondary Heap Leaching with Integrated Data Analysis and Characterization

K. Lang, N. Clayton and K. Hansard; WSP | Parsons Brinckerhoff, Tucson, AZ

Leaching challenges include pooling, channeling, lag & breakthrough times, increased solution in inventory, toe saturation and slope stability, creating recovery shortfalls & raising costs & risks. Advanced borehole wireline and surface geophysics, core sample data & data integration combine to characterize hydrogeology, geochemistry & solution disposition 3D images of solution volume change may be used for near real-time integration of electrical resistivity tomography w/ advanced wireline downhole geophysics measurements of moisture and saturation during leaching cycles. Volumetric fluid content can be estimated with algorithms relating material porosity, fluid saturation of pore volume & fluid resistivity to material bulk resistivity. Core lab analysis & advanced wireline in-situ spectroscopy logging provide 3D characterization of metals distribution & concentrations Techniques presented show the value of reliable characterization and the ability to monitor solution volume and PLS metal & moisture changes for active & historic heap operations. Measurements improve understanding of leaching efficiency & completeness, potentially increasing production and preventing slope failures.

WEDNESDAY, FEBRUARY 22

AFTERNOON

2:00 pm **Room 502**

Mining & Exploration: Management: Project Risk Management

Chairs: *B. Warfield, Consulting, Roseville, CA*
R. Goodfellow, Aldea Services LLC

2:00 pm
Introduction

2:05 pm
Integrating Social Risk into Enterprise Risk Management Approaches

J. Render; Community Contexts, Binghamton, NY

Ongoing feedback from a number of operators and developers indicates that social risk is still a primary area of risk across the sector. The Ernst and Young evaluation of the Top 10 risks for the sector as a whole has included social risk for the past several years, and for 2015-2016, it was ranked as #5. While many companies acknowledge the priority of the subject, they are challenged internally with developing processes that effectively identify, define, and measure this area of risk. The causes of the challenges faced are foundational: a lack of definition of the subject area beyond existing political and EHS uses; a lack of (or conflicting) ownership of the subject area; and a lack of participation of the community relations practitioners in risk assessment processes. This presentation will summarize experience in collaborating with the community relations and enterprise risk groups in a multinational operator to assess the existing risk management tools and develop an enhanced approach to understanding and managing social risk. This presentation will summarize the challenges that needed to be addressed, the tools developed to enhance the methodology, and lessons learned.

2:25 pm
Effective Project Risk Management: from Opportunity Initiation to Project Start Up

S. Cabano; Pathfinder, LLC, Cherry HIll, NJ

The Mining industry can benefit from an expanded view of the Risk Management process as part of the Project Management process. It is fertile ground for project execution improvements, as some still suffer from habits that started during periods when brute force was more important than efficiency. This paper will explore ways to implement an effective process to identify, track, & manage risks by implementing mitigation planning, rigorous follow-up, & corrective action planning. It will also delve into items that may be undetected until significant impact occurs, such as: -Environmental Permitting -Land, mining rights, easement acquisitions -Site restoration requirements -Structural stabilization requirements -Storm water runoff -Spoils containment -Business Case fluctuations -Lean owner teams leveraged through vendors/

contractors -Remote sites -International procurement of large equipment w/ limited supplier options -Cultural Workforce, Operations, & Liaison issues w/ Local Authorities -Etc. By identifying issues early and developing & effectively implementing mitigation strategies, it's possible to achieve safety targets, attain quality goals, minimize cost overruns & reduce schedule delays.

2:45 pm

Structured Finance, Export Credit Agencies, and Large Mining Projects

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

As mining projects around the world become larger and more expensive, the configuration of financial and funding instruments becomes more complex. Most projects require structured financing, involving private equity, governmental support mechanisms, commercial banks, development banks, and/or export credit agencies (ECAs). Increasingly, ECAs play a major role in moving project development and financing forward, even if the ECAs are not the primary lenders. This paper will review typical structures for mining project financing, the role of ECAs, such as the Export-Import Bank of the United States, and will use aspects of recent deals to illustrate the current and future of financing options for large mining projects.

3:05 pm

Quantifying Risk based on Leading Indicators

M. Savit; Husch Blackwell LLP, Denver, CO

New tools to predict and prevent unsafe behaviors are being developed at a rapid pace. They will udoubtedly change our approach to risk assessment by providing a powerful new tool that is both quantitative and behavior based. This paper will explore these techniques and approaches.

3:25 pm

Using the Guidelines for Improve Risk Management in Underground Projects

R. Goodfellow; Aldea Services LLC, Frederick, MD

The Underground Construction Association of SME published their "Guidelines for Improved Risk Management onTunnel and Uunderground Projects in the United States of America" in 2015. These guidelines are being used across the USA on civil projects but they can equally be applied to mining or other underground projects. This presentation will focus on how the guidelines are being used in practice and how the improvement in risk management practices has and will continue to improve project outcomes. Particular emphasis will be given to transfer of risk management tools during procurement as well as the communication of risks between the Owner and Contractor.

3:45 pm

Using the Memory and Cognition of Strategic Mineral Commodities to Predict Price Trends

C. Tapia Cortez[1], S. Saydam[1], J. Coulton[2] and C. Sammut[3]; [1]School of Mining Engineering, UNSW, Sydney, NSW, Australia; [2]Business School, UNSW, Sydney, NSW, Australia and [3]School of Computer Science and Engineering, UNSW, Sydney, NSW, Australia

Forecasting Strategic Mineral Commodity (SMC) prices has become a colossal task due to the intrinsic complexity of uncertain market conditions. The size of the problem increases due to the massive amount of available data, the difficulty in selecting key variables and the complexity to capturing hidden patterns governing systems embedded in high dimensional spaces. There is no single technique capable of overcoming drawbacks above simultaneously; however, each one of them may be solved by particular techniques. Chaos Theory can detect the temporal relation between variables, the dimension and time delay of the system. Principal Component can reduce dimensionality finding relationships impossible to be graphically represented. Machine Learning is capable of seeking hidden patterns in data sets and solving complex problems emulating human learning and decision-making processes. Thus, the representation of the dynamic of SMC prices requires the integration of these techniques. This paper introduces a methodology to forecasting SMC prices integrating Chaos Theory and Machine Learning into computational platform so-called Dynamic Cognitive Mineral Uncertainties Simulator (DyMUS).

WEDNESDAY, FEBRUARY 22

AFTERNOON

2:00 pm **Room 501**

Mining & Exploration: Operations: Rock Mechanics and Geotechnical Challenges and Practical Solutions

Chair: *K. Kocsis, University of Nevada, Reno, Reno, NV*

2:00 pm

Introduction

2:05 pm

Twenty-five Years of Seismic Tomography for Mine Rock Mass Monitoring

E. Westman; Mining and Minerals Engineering, Virginia Tech, Blacksburg, VA

The current practice for engineers tasked with monitoring and assessing the stability of underground openings is to use field observations to calibrate the output from numerical models and a seismic events database. Field observations may not be sufficient to detect problem areas before damage becomes significant. Numerical modeling is a useful tool for understanding rock mass behavior, however results are frequently based on assumed and generalized physical properties within the rock mass. Microseismic data, including event locations and magnitudes, may only give a partial picture of change in the

rock mass. Passive seismic tomography complements the field observation, seismic database and numerical modeling effort. Case studies where seismic tomography has been used to better understand stress redistribution in underground mines will be shared, including examples from both coal and hardrock mines. Results show that this tool can complement existing tools (such as point-location geotechnical monitoring and numerical modeling) to help the engineer better design safe and efficient operations.

2:25 pm 17-010

Analysis of Floor Heave Due to High Horizontal Stresses in an Underground Limestone Mine

B. Slaker[1], M. Murphy[1] and T. Miller[2]; [1]Ground Control Branch, NIOSH - PMRD, Pittsburgh, PA and [2]East Fairfield Coal Company, North Lima, OH

An underground limestone mine in eastern Ohio was experiencing significant floor heave and roof falls, attributed to high horizontal stresses. Areas of the mine showing floor heave were monitored with roof-to-floor extensometers and photogrammetry surveys, to determine the rate and magnitude of heave. Extensometer data were being recorded hourly at four locations across adjacent entries while photogrammetry surveys of the floor were performed at the same locations every two to five weeks. Following instrumentation, floor heave up to 4 inches was measured by both the extensometers and in the photogrammetric reconstructions during a 4 month period. The extensometers were biased by the location they were placed, failing to consistently capture the location and extent of floor heave and cracking. Mining in the area was halted and within several months the floor movement and incidence of roof falls was significantly lessened.

2:45 pm 17-122

Three-Dimensional Slope Stability Analysis of Block Sliding Slope Failure at the Pikeview Quarry, El Paso County, Colorado

J. Varnier[1], J. Cremeens[1] and D. Overton[2]; [1]Knight Piésold and Co., Denver, CO and [2]Engineering Analytics, Inc,, Fort Collins, CO, CO

Slope failures that occurred in 2008 and 2009 at the Pikeview Quarry in El Paso County, Colorado, USA were investigated using three-dimensional discrete element modeling methods. Large scale block sliding failures occurred along weak bedding planes that dip steeply into an excavation located at the toe of the slope. Several mining sequences at the toe of the slope were simulated to evaluate the effects of various degrees of extraction and backfill on slope stability. Slope stability back analysis was conducted using pre-failure and post-failure conditions to determine the joint shear strength properties. Laboratory testing was also conducted to determine intact rock properties. Three-dimensional discrete element analysis was uniquely applicable to this evaluation because it allowed representation of shear stress of the basal sliding surface and it afforded evaluation of several scenarios of extraction and backfill at the toe of the slope.

3:05 pm 17-028

Planning for Hydrogeological Testing Using Inflatable Packers - Lessons Learned with Project Examples

J. White; Golder Associates Inc., Saint Charles, MO

Geotechnical investigations often include a hydrogeological testing component for characterization of groundwater flow and chemistry. The means of isolating water-bearing units can be accomplished through the use of inflatable packers. Often, the testing specialist must be ready to mobilize equipment and personnel with little notice and collect meaningful data from boreholes typically drilled for a primary purpose other than hydrogeological testing. It is essential to coordinate the field program with all project stakeholders at the work planning stage to minimize project stand-by, reduce the likelihood of tool loss or malfunction, and to meet testing objectives. Advocating borehole location, size and orientation considerations for the hydrogeological program can aid in expediting the testing schedule and ensuring representative data collection. Additionally, these considerations have a bearing on the selection of packer equipment, interval length and test duration. This presentation discusses the pre-mobilization planning process, including recommended information to gather from stakeholders and implications of different site conditions on the selection of testing equipment.

3:25 pm

Seismic Monitoring at Barrick's Goldstrike Mines

M. Jamkhana and V. Bonzumah; Underground Division, Senior Mining Engineer, Elko, NV

The Goldstrike property, owned and operated by Barrick Gold, is located in north eastern Nevada, USA, along the Carlin Trend, a 37-mile long north-northwest alignment of sedimentary rock-hosted gold deposits. The company conducts both open pit and underground mining operations at this property. According to USGS, Goldstrike property is in a region of relatively low probability for significant seismic event occurrence. Between April and July 2014, three shallow (<2km) earthquakes of Magnitude ~2.0-2.5 caused ground shaking at Goldstrike operation. The events resulted in preventative mine evacuation and inspection of underground facilities; and no apparent damage was observed. No local seismic stations were in operation at the time and locating the events was highly uncertain. Since then a local surface seismic network and an underground micro-seismic network have been installed to monitor seismic events around the property. The installed system has successfully captured some seismic events since its commissioning. This paper discusses the monitoring efforts currently in place, analysis of events, risk mitigation and improved communication to the workforce for safe underground mining.

3:45 pm

Installation of a Thin Spray-on Liner Ground Support System at the Cote Blanche Mine Production Shaft

R. Howe[2] and G. Sutton[1]; [1]Mining Operations, Cementation USA, Bunker, MO and [2]Strategic Projects, Compass Minerals, Goderich, ON, Canada

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

WEDNESDAY, FEBRUARY 22

AFTERNOON

2:00 pm **Room 503**

Mining & Exploration: Technology: Case Studies & Application of Robotics and Automation at Operating Mines

Chairs: *J. Marshall, Queen's University*
P. Marshall, SME

2:00 pm
Introduction

2:05 pm 17-036

Design of a Novel Auto-Rotating UAV Platform for Underground Mine Cavity Surveying

J. Mitchell; Robert M. Buchan Department of Mining, Queen's University, Toronto, ON, Canada

This paper describes the design and construction of a novel auto-rotating UAV platform for three-dimensional mapping of underground mine cavities or stopes. The purpose of this new approach is to improve the coverage and timeliness of underground cavity mapping at a much lower cost when compared to current cavity scanning methods. This paper describes the application selection, aerodynamic modelling, 3D scan design, and an iterative prototype building phase. The selected design resembles a completely passive system that auto-rotates as it falls through a cavity. An onboard LiDAR sensor gathers a 3D helix pattern that covers the cavity's walls. Scan coverage is expected to be broader than current methods due to the ability to scan from various viewpoints. Thus potentially eliminating shadows due to irregularities of cavity walls. The prototype UAV itself consists of four carbon fibre rotor blades similar to a helicopter rotor that have been designed for a specific flight pattern. A custom built LiDAR sensor payload has been included to collect 3D data and monitor the flight of the UAV. After flying the data from the UAV is processed to generate a 3D map of the underground cavity.

2:25 pm

Innovation in Recovering from the World's Largest Mining Landslide

B. Ross; 90 Degree Consulting LLC, Tucson, AZ

After experiencing the largest mining landslide in the world in April of 2013, Rio Tinto Kennecott's Bingham Canyon Mine was left with thousands of feet of scarps that towered over 600 feet, no access for large equipment in the mine because the main haulroad was destroyed and limited ore because debris had covered more than half of what had previously been exposed. To recover from these issues many innovations were employed or developed with the help of employees, vendors and contractors to return the mine to full production. This paper is based on the new book, Rising to the Occasion – Lessons from the Bingham Canyon Manefay Slide and describes some of those innovations and how they were implemented both quickly and safely.

2:45 pm

Autonomous Haulage Implementation: Focusing Early Efforts to Deliver Long Term Results

C. Smith and J. Barnwell; Global Mining, Caterpillar, Perth, WA, Australia

Early implementations of autonomous haulage fleets are typically done in a segregated area of an operational mine and allocated dedicated machinery and personnel for production and support. Mine operators are curious to trial autonomous operations in this controlled environment for a variety of reasons. Primarily, it allows them to adapt their processes and procedures as well as analyse the productivity of the technology in their particular application. The difficulty with doing so in a captive environment is that the resources available to the broader mining operation might not be fully afforded to the isolated operation. Productivity and perceived effectiveness of the autonomous fleet are impacted, and this can prevent miners from realizing the full potential of the technology. This article discusses some of these operational barriers and potential pitfalls to help adopters achieve early results and sustained performance. The authors make use of system dynamics and value based management techniques to identify key value drivers that will help miners focus their efforts on maximizing the value of autonomous haulage at this critical stage.

3:05 pm

Creating Value with Semi Autonomous Tractors

K. Stratton; Research, Caterpillar Inc, Dunlap, IL

A lot has been accomplished on autonomous machines in recent years. Clearly, the haulage solution has been address, however the challenge in many application continues to be meeting all of the customer requirements and creating real customer value in the mining environment. Dozers in particular are very challenging in that they are consistently changing their environment and interacting with the earth and rocks which have inherent uncharacterized variations that challenging existing control capabilities. Caterpillar has accepted that challenge and developed a unique planning system, optimized our human-machine interface and significantly adapted existing control systems to provide the ability for one operator to control 4 machines while meeting or exceeding the performance of an on-board operator. This paper will describe the challenge, the research completed to address the challenge and examine the results.

3:25 pm

Advances in Automation Techniques for Copper Ore Sample Processing

J. Nunley[1], C. Deem[2] and J. Sweet[2]; [1]Safford Mine, Freeport-McMoRan, Safford, AZ and [2]Technology Center, Freeport-McMoRan, Safford, AZ

The Central Analytical Service Center (CASC) provides analytical support for Freeport-McMoRan's mining operations. The CASC is responsible for timely processing of solid and liquid samples taken from exploration, mining, milling, and hydrometallurgical operations in North America. In 2015, the CASC completed construction of Line 5; an automated blasthole and exploration processing line. Line 5 was designed to integrate a fully automated sample preparation circuit with an automated wet chemistry cell. This state-of-the-art robotics line offers the ability to process an additional 500 blasthole samples per day and expands the lab's capability to process 125 exploration drill core samples. This system includes several novel design features intended to improve quality, reliability and functionality over existing automated systems used at the CASC, and in the industry. An overview of some of these features, and the challenges realized in implementing them, will be provided in this presentation.

3:45 pm

Maps of Structural Discontinuities Created Using Data Collected with a Robot-Mounted Mobile Lidar, a Stationary Terrestrial Scanner, and Traditional Manual Methods: Case Study Comparison from the Edgar Experimental Mine, Idaho Springs, Colorado

J. Meyer; Mining Engineering, Colorado School of Mines, Golden, CO

Workers in the mining, underground civil construction, and exploration industries create geological maps of voids containing structural data regarding discontinuities such as bedding surfaces, joint faces, and fault planes. These maps enable workers to make informed decisions regarding rock engineering applications. These maps are commonly produced using traditional manual collection and processing methods which can be subject to sampling bias, inaccurate, and expose workers collecting the required data to hazardous conditions. Raw data from a case study area in Colorado School of Mines' Edgar Experimental Mine were gathered using three collection methods: A LiDAR mounted on a mobile robotic platform A stationary terrestrial LiDAR A traditional manual discontinuity survey Digital point cloud data collected with the mobile and terrestrial LiDAR were analyzed using automatic and manual interpretation methods, while data collected using traditional methods were analyzed using manual interpretation. An analysis of the accuracy of, and time required to produce, structural maps created using three collection methodologies was performed, differences quantified, and results presented.

4:05 pm

Autonomous Trucks in Mixed Traffic. A Digital Revolution!

P. Burman, Skellefteå, Sweden

"How to use new digital technology in mining is the hot topic within the industry. Many companies are just starting to investigate the benefits and opportunities of leveraging the huge advancements in equipment, software and communication systems in the digital age. For several years now Boliden has worked towards a vision to digitalize its underground mines. Today we have Wi-Fi and 3D positioning services in all of our Swedish mines. By the end of 2016, the total number of installed access points passed two thousand. Boliden is now leaping forward, taking the next step in digitization, with the first tests of an autonomous truck from Volvo underway. We are convinced that these newly designed, remotely operated and autonomous machines will revolutionize mining. The future is already here!"

WEDNESDAY, FEBRUARY 22

AFTERNOON

2:00 pm **Room 504**

Mining & Exploration: Technology: Leveraging New Technology in Spatial Data and Geostats Modeling from Exploration to Mine Closure

Chairs: *R. Cooper, Newmont Mining, Colorado Springs, CO*
I. Allen, Barrick Gold Corporation

2:00 pm
Introduction

2:05 pm 17-102

Real-Time Integration of Production Sensor Data for Improved Grade Control

J. Benndorf[1] and M. Buxton[2]; [1]Geomonitoring and Mine Surveying, University of Mining and Technology Bergakademie Freiberg, Freiberg, Germany and [2]Geosciences and Engineering, Delft University of Technology, Delft, Netherlands

Advanced data acquisition and process modelling technology provides online data and decision support about different aspects of the resource extraction process. Real-time approaches have recently been applied to utilize the value of this information for improved production control in mineral resource extraction in different operational set ups including coal, polymetallic ore and gold deposits. The key concept of these approaches promotes the change in paradigm from discontinuous intermittent process monitoring to a continuous process and quality management system. The framework includes a real-time feedback control loop that rapidly links online material characteristics data acquired during extraction, material handling and processing with a sequentially up-datable resource model. The contribution reviews recent developments in the three main constituents sensor based material characterisation, rapid updating of grade control models and simulation based optimization for improved production control. Technological readiness is assessed and critical gaps for further technology development are identified. The value added is illustrated by means of selected case studies.

2:25 pm

Real-Time Updating of the Geomet Model based on Ball Mill Performance Measurements - a Case Study at the Tropicana Gold Mine

T. Wambeke[1], P. Ketelaar[2], J. Benndorf[3] and R. Peattie[2]; [1]Delft University of Technology, Roosendaal, Netherlands; [2]Anglo Gold Ashanti, Perth, WA, Australia and [3]University of Mining and Technology Bergakademie Freiberg, Freiberg, Germany

The ball mill is usually the single largest energy consumer at a mine site and significantly affects operational expenditures. Given a target particle size, work index estimates are used to predict mill throughput. In order to

maximize the mill throughput and ensure an optimal energy utilization, it is important to get the work index estimates right. The work index estimates generally originate from spatial models derived from sensor data collected during drilling. Inaccuracies exist due to ill calibrated relationships between sensor data and laboratory work index values. Instead of relying on a limited number of metallurgical tests, a novel updating algorithm was used at the Tropicana Mine to continuously update work index attributes based on online mill performance data. Deviations between predicted and actual mill performance were monitored and used to locally improve the spatial estimates. A continuous self-learning took place and the prior spatial model converged towards the previously unknown reality. Updates did not only result in a real-time reconciliation of extracted blocks but also significantly improved estimates in blocks to be mined in the future.

2:45 pm

Geologic Modelling of Complex Orebodies: Combining Deterministic and Probabilistic Models

M. Rossi[1], T. Strong[2] and P. Brown[3]; [1]GeoSystems International, Boca Raton, FL; [2]Kangari Consulting, Launceston, Cornwall, UK and [3]PB Geological Consultants, Ryde, Isle of Wight, UK

The most important aspects of a deposit's geology should be modeled to condition and constrain the estimation of its resources. There are many complex mineral deposits that evidence multiple geologic controls on mineralization. Birimian-type gold deposits, to name a few, often evidence a combination of structural, lithological, and alteration controls, resulting in complex spatial patterns of mineralization. Usually geologic controls are modeled either through interpretation on sections/plans of three dimensional shapes, or through implicit modeling techniques. The resulting wireframes are used to control the grade estimation process. But there are instances where those shapes cannot consider all the existing controls in the deposit, and thus a fraction of the resource is estimated without controls, or not considered at all in the resource estimate. The controls that cannot be modeled explicitly can be represented using geostatistical techniques. A combination of deterministic and probabilistic modeling is proposed to improve the geologic modeling of complex gold deposits, and in so doing improve the resource estimate. An example is described from a West Africa gold deposit.

3:05 pm

Balancing Optimal and Practical Selective Mining Units

M. Rossi; GeoSystems International, Boca Raton, FL

This paper proposes a methodology to determine a practical Selective Mining Unit (SMU) for resource and reserve modelling within the context of an operating mine. This practical SMU is intended to represent operational selectivity based on specific mine plans and mine equipment. The practical SMU is derived from the theoretical SMU, which is optimal in the sense that it provides the most value if the operation was entirely flexible. In the approach proposed here, this optimal SMU is modified by considering the existing operational dilution; areas where this operational dilution can be improved upon; and areas where there is unavoidable dilution or loss of selectivity. The resulting practical SMU can be represented in the resource and reserve models such that mine plans derived from them will better reflect expected grades and tonnages delivered to the plant. In this paper, several real-life examples are discussed to illustrate the approach.

3:25 pm

Mineral Prospectivity Modeller (MPM) – New GIS Tools for Mineral Exploration

V. Nykänen; Digital products and services, Geological Survey of Finland, Rovaniemi, Finland

Increasing amount of digital data collected during mineral exploration requires enhanced data-analysis methods and practices that can also be considered as time-saving, cost-effective and environmentally neutral exploration techniques. The MPM project investigates and implements new workflows and tools for mineral prospectivity modelling. To support target scale mineral exploration, a public Spatial Data Modeler toolbox is redesigned and recoded into ArcGIS. To support strategic planning of exploration companies, the project produces an on-line prospectivity modeller for selecting target areas for exploration. The use of the tools will be demonstrated in a case study with real exploration data. The results of the project will be published as a report of investigation, scientific papers and an open source software. The project is co-funded by a Finnish national funding instrument called TEKES, together with the mining and exploration industry. The MPM project will involve an international collaboration network composed of the top experts in mineral prospectivity mapping from the U.S. Geological Survey, the Geological Survey of Canada and the University of Campinas (Brazil).

WEDNESDAY, FEBRUARY 22

AFTERNOON

2:00 pm **Room 703**

MPD: Comminution II

Sponsored by thyssenkrupp Industrial Solutions

Chairs: *T. Winkelman*
K. List, Weir Minerals, Old Hickory, TN

2:00 pm

Introduction

2:05 pm

A Review of Available on-Line Particle Size Analyzers

M. Larson; Consultant, Ewen, MI

On line particle size analysis is not a new concept, however a great many concentrators still do not employ this control method. A thorough review has been completed of both familiar machines along with newer options. It is hoped this can generate discussion on whether new designs simply over complicate matters, or offer improvements such that more mills can successfully utilize these in monitoring and control of their circuits.

2:25 pm

Vertical Roller Mills – the Next Step in Energy Efficient Grinding

M. Carlisle and J. Dziedzina; SME, Midvale, UT

Vertical Roller Mills (VRMs) have achieved remarkable success and growth in dry grinding applications in the cement and allied industries, but have yet to gain traction in the minerals industry. This is despite the fact that they have tremendous potential to either replace SAG mills in conventional grinding circuits, replace HPGRs in hybrid circuits or to completely replace the conventional milling circuit in a cost effective dry grinding application (where conditions allow). In a desktop study, five circuits were evaluated for capital cost, energy consumption and wear materials (including grinding media) consumption. The study indicated that there was little difference in up front capital costs for the VRM circuits compared to conventional and HPGR milling circuits, but operating costs show significant benefits through the elimination of, or reduction in, the use of grinding media and the reduction in energy consumed to achieve a given grind. The significant downstream benefits that accrue from dry grinding and dry separation are also considered.

2:45 pm

Scaling Back on Scale: Eliminating Production Losses from Mill Water Upsets

D. Steiner[1], D. Wayman[1], N. Morrison[2], R. Nivens[2], C. Sui[2] and U. Turunc[2]; [1]KGHM Robinson Nevada Mining Company, Ruth, NV and [2]Water & Process Technologies, GE Power, Lebanon, United States Minor Outlying Islands

In most copper mines and concentrators mill water is continuously recovered and reused, with fresh water added to make up for losses. When mixed, these water chemistries can lead to severe scaling, especially in pipes, tanks and pumps on the mill water supply side, reducing flows and causing significant production losses. At Robinson Nevada Mining Company, steady increases in ore throughput combined with changes in the ore body resulted in severe scaling problems and pre-mature pump failures thereby jeopardizing plant production. What initially appeared to be a few isolated scaling events eventually unfolded into a recurring pattern of water supply related production losses with increasing severity. Through completion of detailed root cause analysis, chemistry modeling, laboratory work, in-plant testing and system engineering the mechanisms of scaling were identified and addressed. Advancements in antiscalant application methods and make-up water addition practices resulted in a stepwise reduction of the mill water scaling. Cost savings and production benefits were significant to the plant's financial metrics.

3:05 pm

Dynamic Modeling & Simulation of a SAG Mill for Characterization of Mill Charge

V. Srivastava, T. Ghosh, G. Akdogan and R. GANGULI; Mining Engineering, University of Alaska Fairbanks, Fairbanks, AK

Modeling and Simulation of SAG Mill has been widely used in design and optimization of mill performance in terms of its power draw, processing capacity and product size distribution. However, these models are solved under steady approximation and do not provide any information on mill charge distribution in real time. This paper attempts to characterize mill contents by solving Whiten's first order contents based model in Matlab/Simulink environment. The parameters in the model such as breakage rate (S), discharge rate (D) and appearance function (A) were estimated utilizing process and design data collected from a gold mine operating in Alaska coupled with nonlinear parameter estimation scheme. This model is then utilized to predict dynamic response of other key operational variables such as mill power, bearing pressure, charge level and product size distribution. The transient response of mill behavior subject to changes in feed size distribution, tonnage and mill feed water is also presented. This dynamic simulation approach can be used for practicing different control strategy and training purposes.

3:25 pm

Two-Mass Vibrating Screens for High Tonnage Applications

G. Beerkircher[1] and E. Wipf[2]; [1]General Kinematics, Waukesha, WI and [2]Ed Rock Man IV LLC, Wonewoc, WI

As mine size and tonnage continues to increase, material handling/processing equipment has also increased in size with 400 MT haul trucks, 2000 KW crushers, 12 M SAG/AG mills, 8.5 M ball mills, 3000 M3 flotation cells and 12.5 MW HPGR's all with planned designs to increase in size further. Related equipment including vibrating screens have also increased in size with screens seeing feed rates of 3000 MTPH. Open circuit SAG Pre-Crush and closed circuit HPGR flowsheets are becoming more common with large screening requirements. Large multi-slope (banana) or horizontal screens are commonly used for these applications, however as the size of these screens has increased, the number and size of the brute force/overhead exciters has increased but with limitations. paper will present some actual examples of the use of Two-Mass screens as a solution to these overloading problems and the advantages of Two-Mass screens in other high tonnage applications.

3:45 pm

HPGR and Air Classification - a Case Study

T. Lundquist; Weir Minerals, Frederic, WI

At this point it's safe to say HPGR's are proven in diamond, copper, and iron ore applications. Even in gold, HPGR has become popular for heap leach mines. There are enough installations with enough different customers from enough manufacturers to say the HPGR has officially arrived. However, when it comes to unproven installations or thinking outside the box there remains industry hesitation. This paper will outline a new application utilizing HPGR and air classification to make a limestone filler product. It will detail the product being made, the circuit used to make it, and the steps along the way to full production. The intent of this paper is to not only explore this new application but to get people thinking about other new areas where HPGR could be beneficial. Until the industry fully embraces HPGR in all possible applications the technology will never be able reach its full potential.

4:05 pm

Study of the Material Slip in High Pressure Grinding Rolls Based on DEM Simulations

G. Pantoja Barrios and L. Tavares; UFRJ/COPPE/LTM, Professor, Rio de Janeiro, Rio de Janeiro, Brazil

Extrusion is a phenomena in high pressure grinding where the compressed bed of particles exits between the rolls at a speed greater than the tangential rolls speed. The speed difference indicates that slip occurs between the product and the rolls surface. Until now, the only evidence for slip in HPGRs follows from the comparison of the theoretical with the experimental throughput. For the calculating of the theoretical value, the relative bulk density at the compressive zone has to be know, which cannot be measured directly and is estimated from the product flake density. Nowadays the advanced modeling of HPGR based on Discrete Element Method, can describe with high level of detail operational features as material hold up distribution, particle velocity, and bed particle compressive force along the compression zone of the HPGR. The HPGR DEM simulations consider important operational variables as the tangential velocity and surface design of the rolls, the compressive force applied to the bed of particles and particle size distribution of the feed. The present work shows the importance of the HPGR DEM simulation as a tool to understand analytically the phenomena of extrusion.

4:25 pm 17-133
Larger Tonnages, Larger Crushers?
K. Boyd; SME, Qualicum Beach BC, BC, Canada

Can the ever-increasing tonnages of ore and waste being mined today be accommodated simply by using bigger and better crushers? This paper reviews the latest primary crushing and large cone crusher designs. It highlights how—in addition to using the larger crushers now available—maximizing the utilization percentages in each of the four stages of the rock size reduction circuit will assist in meeting the larger production requirements of existing and new mining operations. Its goal is to help consultants and operators select the optimal equipment and custom-designed items in the material handling flowsheet from the mine to the mill, maximizing operating hours per year.

WEDNESDAY, FEBRUARY 22
AFTERNOON

2:00 pm Room 705
MPD: Flotation Equipment and Plant Operations

Chairs: *J. Gebhardt, FLSmidth Salt Lake City Inc, Midvale, UT*
A. Noble, West Virginia University, Morgantown, WV

2:00 pm
Introduction

2:05 pm 17-084
Metallurgy, Process Control and Mineralogy Integration at the Kittila Mine Finland

R. Thorpe[2], R. Mermillod-Blondin[3], A. Niiranen[4], P. Gottlieb[1], J. Ruokanen[4], A. Kopriva[1], M. Dosbaba[1] and A. Palko[2]; [1]TESCAN ORSAY HOLDING a.s., Brno, Czech Republic; [2]Metrix Plant Technologies, Parkesville, BC, Canada; [3]Technical Services, Agnico Eagle, Preissac, QC, Canada and [4]Kittila Mine, Agnico Eagle, Kittilä, Lap Land, Finland

Automated Mineralogy (AM) is an important diagnostic tool in flotation plants as it adds ore and particle mineralogical properties to traditional mass and chemical data. AM is used in project development, for future ore studies and for diagnosing concentrator operations. With the exception of operations who own central laboratory or on-site systems, the use of AM is often limited to the analysis of a comparatively small set of samples. Metrix Plant Technologies has partnered with TESCAN to integrate TIMA AM technology into the implementation of Performance Assessment Campaigns (PAC). Routine daily composite samples from the mill are analysed mineralogically on a size-by-size basis over several weeks. All the relevant metallurgical, process control and mineralogical data is combined into a single large database for mass balancing and interactive examination. This paper describes the implementation and results of a PAC at the Agnico Eagle Kittila gold mine in Finland. Although challenging, the addition of mineralogical data as dependent variables in multivariate analysis leads to a much deeper understanding of the root cause effect of events driving the flotation performance.

2:25 pm
Development and Testing of the nextSTEP Technology, an Energy-Efficient Flotation Rotor Designed from Fundamental Research

A. Noble[1], Y. Yang[2] and L. Riffo[2]; [1]Mining Engineering, West Virginia University, Morgantown, WV and [2]FLSmidth, Salt Lake City, UT

Mineral concentrators around the world are under pressure to reduce power consumption and operating costs while retaining metallurgical performance and process efficiency. To address this need, an academic-industrial research partnership has assessed the role of rotor/stator design in influencing energy dissipation and the resultant flotation kinetics. Scale modeling, fluid velocity profiling, and other fundamental tools were used to identify the energy consuming sub-processes that occur in a conventional flotation cell. With this fundamental knowledge, CFD modeling was used to design a new rotor geometry that minimized wasteful energy consumption by creating a more uniform slurry velocity at the rotor tip. The resultant rotor lowered power draw, reduced wear rates, and actually improved metallurgical performance when compared to several alternatives. These findings have been verified across all operating scales from the laboratory to industrial installation. This paper presents data from these studies to demonstrate the potential for improved metallurgical performance and to demonstrate how basic research can lead to step changes in machine design.

2:45 pm
Hydrodynamic and Metallurgical Evaluation of the 600 Series SuperCell in Industrial Application

K. Caldwell, Y. Yang, C. Christensen and D. Lelinski; Research and Development, FLSmidth, Draper, UT

Flotation cells are getting bigger and more efficient. Until recently, the FLSmidth 300 Series SuperCell™ was the largest in the world with a capacity over 300m3. In 2011 FLSmidth started the development process of the new

generation of flotation cells and the final result is the 600 Series SuperCells™ with volume starting at 600m^3.The first 600 Series SuperCell™ has been installed, tested and is operating as a rougher scavenger at the Robinson Mine. In addition to new, large throughput plants, these cells are especially attractive in a situation when there is limited room for expansion in existing large capacity plants. Hydrodynamic and metallurgical response of forced air mechanisms evaluated will be presented with the emphasis on the nextSTEP™ rotor/stator combination. The nextSTEP™ technology has shown superior metallurgical recovery as well as a significant increase in energy efficiency in all stages of testing. CFD models show that flotation recovery is increased because of improved turbulence dissipation which enhances bubble-particle attachment rate. Presented results will include hydrodynamic scale up, characterization and validation, RTD and metallurgical results.

3:05 pm

Simulation of Venturi Tube Design by CFD for Pico and Nano Bubbles Generation

F. Peng and W. Wang-Geissler; Mining Engineering, West Virginia Universitiy, Morgantown, WV

Hydrodynamic cavitation is the most economical method to create tiny bubbles for coal and mineral flotation. Efficiency and design geometries of the devices are analyzed using CFD in this study. Mathematical models were validated through comparison with published geometries and experimental results. Circular venturi tubes were found to be the best design for cavitation tiny bubbles generation. To optimize design of venturi tube, six key parameters were examined. These include inlet diam, inlet and throat diam ratio, convergent and divergent angles, throat and entrance lengths. Interactions and effects of the parameters on pico and nano bubble generation are evaluated. A two-phase cavitation model based on Eulerian and κ - ε models were applied. Inlet and throat diam ratio is founf the most significant factor. It has the greatest impact on critical velocity for cavitation. Example of optimal designed venture tube for pico-nano bubble generation will be presented and discussed. Fully understand parametric relationships for venture tube design, distribution of cavitation bubbles sizes can be calculated for wide ranges of applications in mineral and waste water processing/treatments.

3:25 pm

High Shear WEMCO Disperser Industrial Test

K. Caldwell, K. Rahal, Y. Yang and D. Lelinski; Research and Development, FLSmidth, Draper, UT

Through a series of laboratory flotation tests the interactions and effects of new rotor, hood, and disperser designs for the Wemco flotation machine were tested. From the test work, it was determined that recovery could be greatly increased from the current baseline. The DOE analysis found that the variable with the most significant effect on the recovery was the disperser. The most promising design is using a disperser that increased the amount of shear produced in the rotor/disperser zone. The new design implements high shear blades in the cell disperser. The addition of the blades increases the turbulence within the disperser. From previous work in the lab, pilot and CFD the increased turbulence led to an increase in flotation performance. The high shear disperser is now currently installed in an industrial flotation application. This paper will discuss the development, laboratory testing, results of the industrial test work as well as the cell characterization.

3:45 pm

Investigation on Froth-Pulp Interactions at High-Speed Frame Rates

Q. Huang, A. Noble, L. Leoncio Cruz Santos and L. Nugent; Minining Department, West Virginia University, Morgantown, WV

Much of the prior research in flotation hydrodynamics has primarily focused on either froth or pulp separately. Direct observations of the phenomena occurring as a bubble is transferred from the pulp to the froth are rare and limited to date. To address these shortcomings, the current study has used a specially-designed flotation cell to investigate the froth-pulp interface (FPI) in a two-phase froth-liquid system at high speed video rates up to 17,800 frames per second. The unique flotation cell is extremely thin (2.5 cm) and constructed of transparent material to permit adequate lighting. The cell also has two separate chambers: one turbulent zone where bubbles are generated and a froth is formed and a second quiescent zone where individual bubbles can be released and monitored. The current experimental program has investigated the impact of frother characteristics, gas velocity, and agitation energy on the FPI behavior. The resultant data are used to define the observed phenomena with respect to bubble size, froth velocity, froth stability, and solution chemistry. These results may be incorporated into the future development of predictive models of bubble behavior at the FPI.

4:05 pm

Mitigation of Covariates Effects in the Flotation Results of a Plant Trial

F. Fernandes Pinto, N. Gantumur and J. Arias; Oil and Mining Services, Clariant Corporation, Tucson, AZ

Froth flotation is a process that is affected by many variables, which naturally have random variation. This study shows the statistical benefits of removing the effect of co-variables and is based on the flotation results obtained during a gold flotation plant trial. The random variation of the ore feed grade created a bias on the effect of the collector change. Multiple linear regression indicates that gold feed scaled linear coefficient is 6 times higher than the effect of changing the collector, which means that 30% variation in the gold feed grade totally negates the effect of changing the collector.

4:25 pm

Copper – Molybdenum Separation from Bulk Concentrate – Recent Considerations

E. Blanco; FLSmidth, Herriman, UT

The recent development in the processes of Copper – Molybdenum separation are reviewed along with its main features. The need for development of processes to separate MoS_2 with less contaminant and better Mo grade from copper bulk concentrates is indicated. Variations of pH' range using H_2SO_4 and/or CO_2 (g), inorganics/organic traditional chemical reagents, alternative NaSH green environmental replacement, Sea/local water type, mineralogy characterization of bulk concentrate, mechanic forced/auto-suction air on flotation cells, kinetics flotation, redox potential measurements, design flowsheet considerations, talc contaminants in final MoS_2 concentrate and alternatives solutions are discussed in this paper.

WEDNESDAY, FEBRUARY 22

AFTERNOON

2:00 pm **Room 707**

MPD: Pyrometallurgy

Chairs: *B. Mota, Safford, AZ*
D.Connor, Metso Minerals Industries Inc, Waukesha, WI

2:00 pm

Introduction

2:05 pm

Rare Earth Magnet Recycling and the Selective Sulfation Roasting of Rare Earths from NdFeB Magnet Scrap

B. Carlson and P. Taylor; Kroll Institute for Extracitve Metallurgy, Colorado School of Mines, Golden, CO

Rare earth magnets play an increasingly important role in high end technology, and the manufacture of these magnets, such as the NdFeB type, consume a large amount of the rare earths produced. Recycling of this material could provide an important domestic source for these materials. An overview of the rare earth magnet recycling efforts at the Colorado School of Mines is presented, including work on the development of a selective sulfation roasting process. To determine the kinetics of this process, a thermal gravimetric apparatus is constructed and the sulfation of iron oxide and neodymium oxide are studied under different experimental conditions. This process is shown to effectively separate the high value rare earth components from iron, the major component of this waste stream.

2:25 pm

Viscosity and Density of Sodium-Iron-Silicate Slags

D. Schriner[1], P. Taylor[1] and J. Grogan[2]; [1]Colorado School of Mines, Golden, CO and [2]Gopher Resource, Eagan, MN

In addition to the chemical properties, the physical properties of a slag (viscosity and density) play an important role in controlling transport phenomena encountered in a blast furnace. The purpose of this investigation was to determine physical properties of a sodium-iron-silicate slag system. Measurements of synthetic slags of varying composition were recorded from 1300-900°C in a vertical tube furnace under an argon atmosphere using a concentric cylinder viscometer and analytical balance. Functions of temperature and composition were then found for the synthetic ternary system.

2:45 pm

Development of the Continuous Bottom-Blowing Matte Converting Process

X. WANG; China Nonferrous Metal Industry's Foreign Engineering and Construction Co., Ltd., Beijing, China

This Paper describes the continuous bottom-blowing matte converting process, as well as the pilot plant test conducted for this process. The pilot plant test shows that under three-phase conditions in the bath, sulfur in blister is

0.7%-1.0%, and Cu in slag is 8-12%; while under two-phase conditions, sulfur in blister is 0.2%, and Cu in slag is around 20%. During the test, oxygen lance and refractory linings are under good conditions. Therefore, it can be concluded from the pilot plant test that continuous bottom-blowing matte converting process has good application prospect.

3:05 pm

A Novel Smelting Method for Continuous Production of Magnesium Metal

B. Chubukov, s. rowe, A. Palumbo and A. Weimer; Chemical Engineering, CU-Boulder, Boulder, CO

Smelting of magnesium ore by carbothermal reduction (CTR) has the potential to significantly reduce operational costs relative to reduction by ferrosilicon or magnesium chloride electrolysis. The greatest challenge in the CTR process is the effective separation of magnesium vapor and CO by-product, which can recombine unproductively. Research at CU-Boulder has helped to reveal the fundamental reaction and transport mechanisms that govern the overall process. Experimental investigation and theoretical modeling of the generation and condensation of magnesium vapor has allowed for the design and construction of a prototype system (100g Mg/hr). Evaluation of the prototype system will be used for scale-up design of a pilot-plant system.

3:25 pm 17-018

Breaking the Wall of Asm Mercury Pollution: the Lantern Retort

R. Amankwah, D. Adjei and G. Ofori-Sarpong; Minerals Engineering, University of Mines and Technology, Tarkwa, Ghana, Tarkwa, Ghana

Mercury (Hg) is toxic and has long-term effect on the muscle tissues, the brain and the central nervous system functions due to its bioaccumulation and biotransformation effect. Hg pollution around the world is high and this has attracted much global concern such as the Minamata Convention on Mercury, held in 2013. For several years, mercury has been the chemical of choice for Artisanal and Small-Scale (ASM) gold extraction, accounting for about one-third of the global mercury consumption. A greater percentage of this end up in the environment through open burning of amalgam, spillage and indiscriminate disposal of waste. To break this wall of mercury pollution, it is very important for the mercury used to be recycled through the use of mercury retort units. This brings into the limelight, the Lantern Retort which tries to synergise the high conductivity of steel and the see-through effect of glass thus improving the amalgamation process. A research conducted on improving the original Lantern Retort arrived at an appropriate distillation length of 5.08 cm which was used in redesigning a more efficient retort. The improved Lantern Retort recovered about 98% of the mercury used.

3:45 pm

Antimonate Capacity of Nickel Matte Converting Slags

R. Reddy; Met. Matls. Eng., The University of Alabama, Tuscaloosa, AL

An extension of the thermodynamic Reddy-Blander (RB) model for deriving a priori predictions of antimonate capacity between the Ni mattes and Ni matte converting slags was developed. The antimonate capacities in the Ni mattes and Ni lime ferrite slags and Ni fayalite slags, and Ni + Cu mattes and Ni-Cu fayalite slags systems were evaluated at 1523 or 1573 K and various pSO_2. Higher antimonate capacities were obtained in Ni ferrite slags. Good agreement between the RB model calculated data and the reported experimental data for antimonate capacity in the above systems was observed. The antimony distribution ratio between mattes and slags were also calculated. The developed model can be applied to industrial processes and improve the efficiency of antimony removal from the Ni mattes converting processes.

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