September 2015
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Mining engineering

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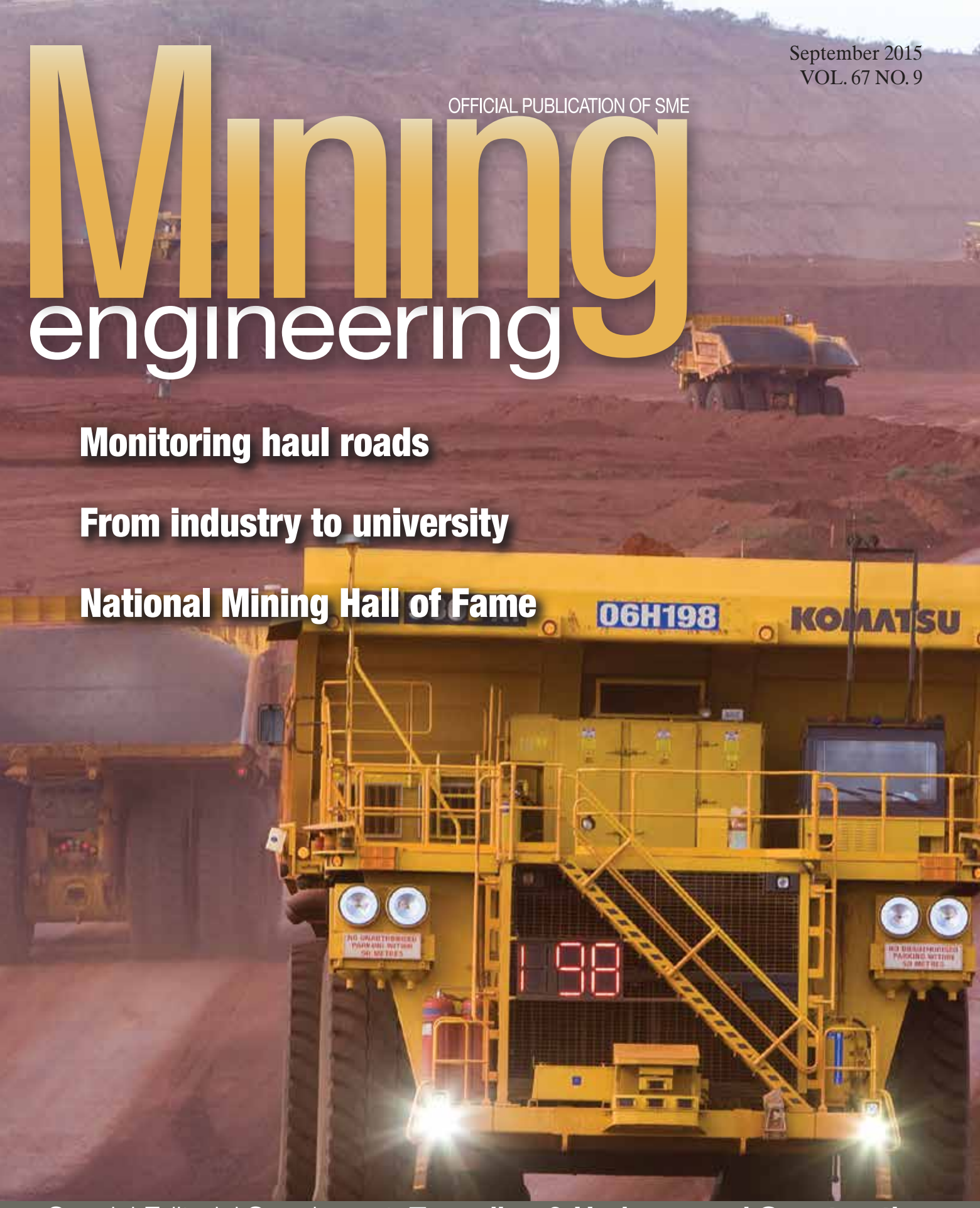
Monitoring haul roads

From industry to university

National Mining Hall of Fame



Special Editorial Supplement: **Tunneling & Underground Construction**

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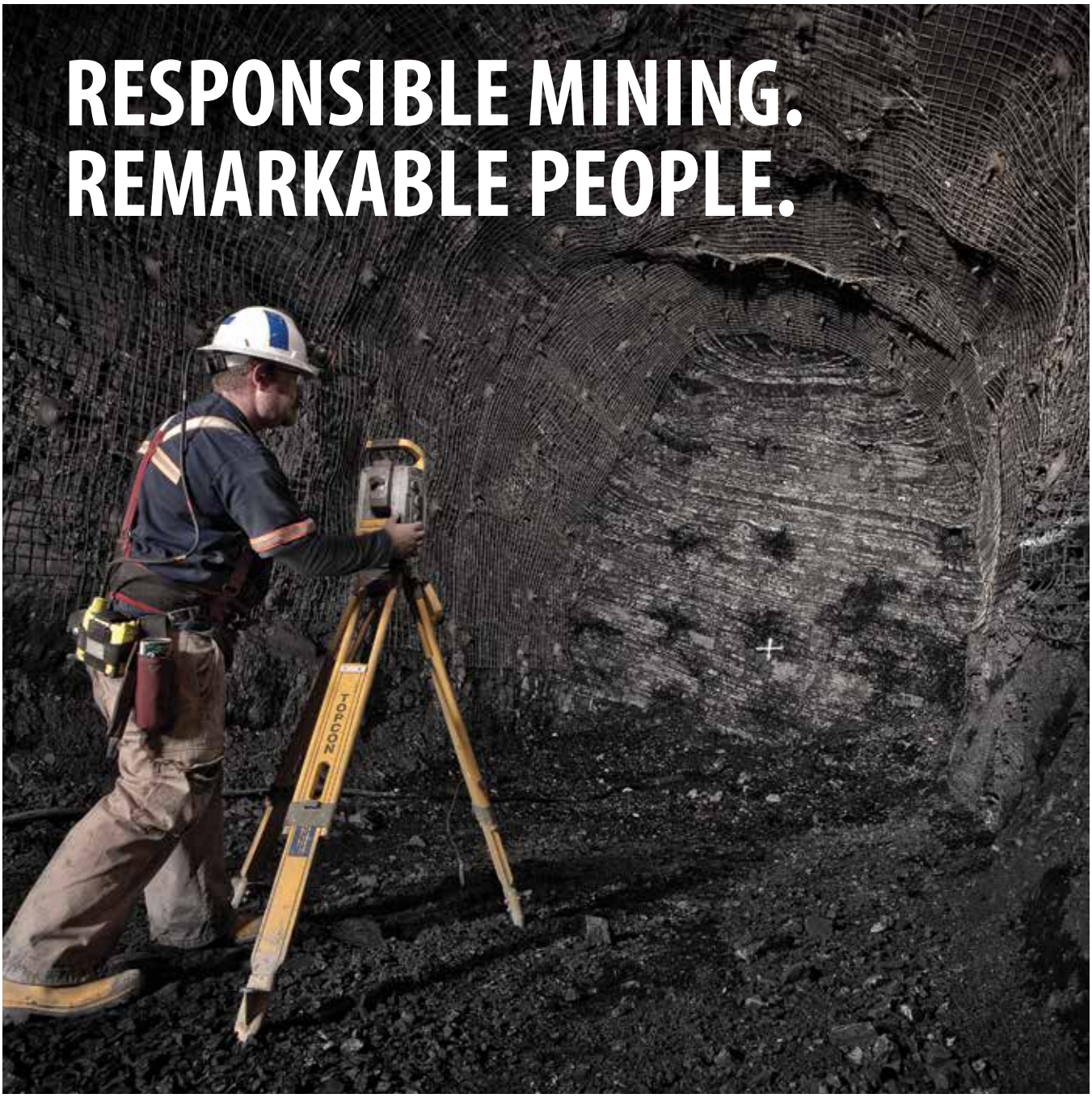

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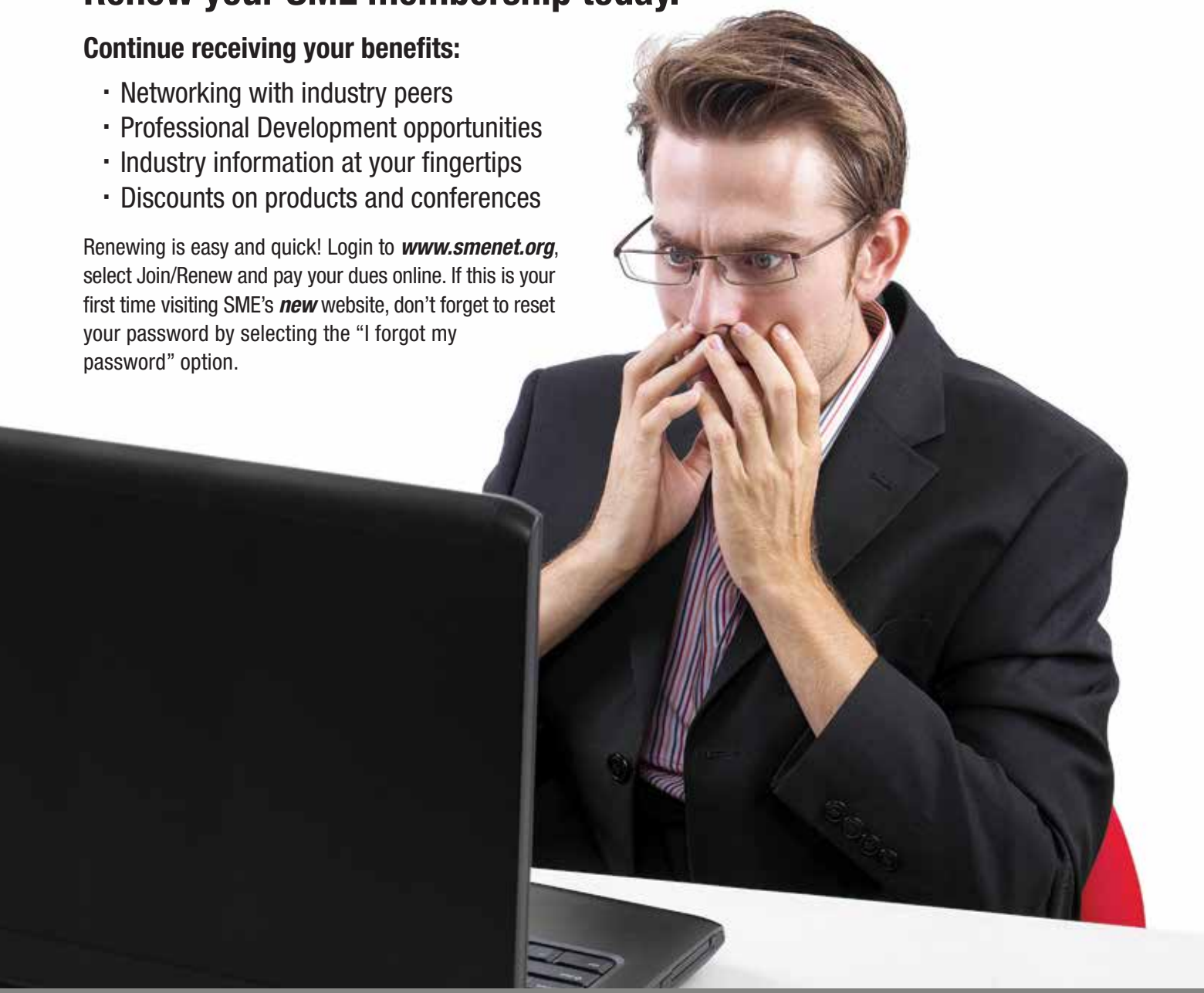

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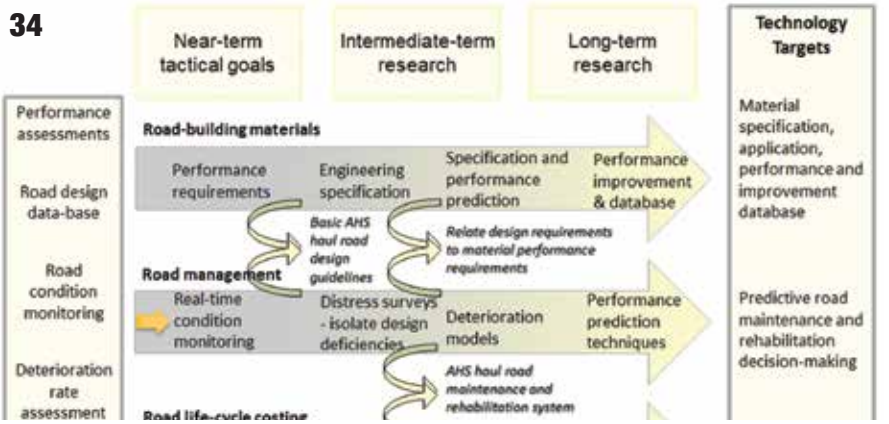

Feature Articles

Technical Papers (peer-reviewed and approved)

Special Editorial Section
Tunneling & Underground Construction

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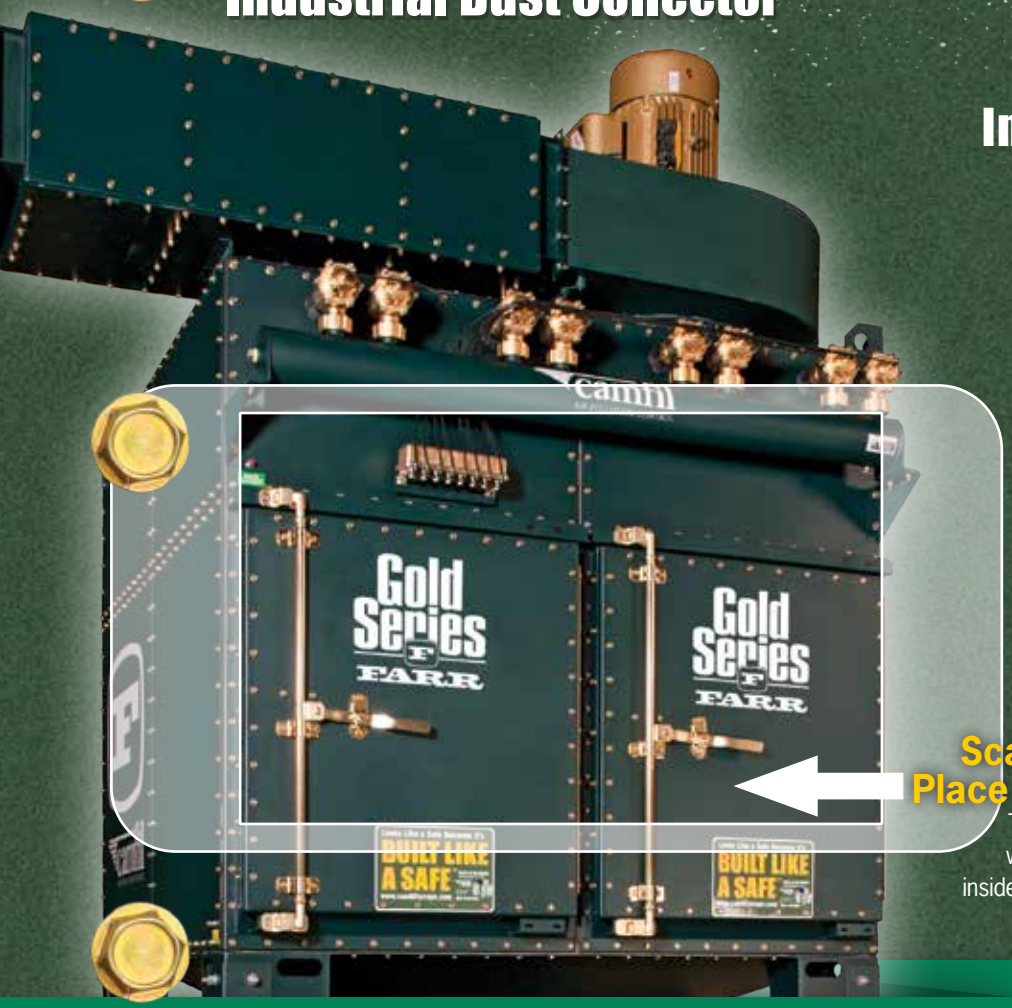

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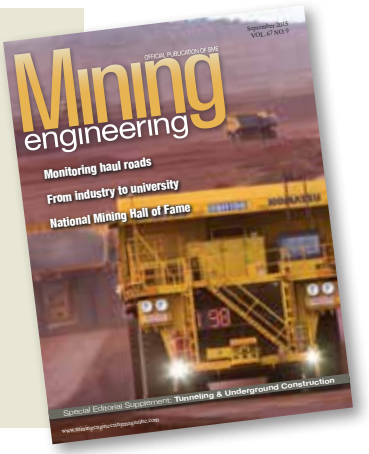
SME News



Departments

Cover Story
As the concept of autonomous haulage systems moves from prototypes to production-ready applications, the operating performance of the haul road will become critical to the overall success of autonomy in mining. A description of surfacing condition monitoring through digital image processing begins on page 34. Moving from more than 30 years of working in mines around the world to the classroom is quite an experience. S.D. Rosenthal describes his experience on page 46. SME is getting a fresh look. Read what these changes will mean to you beginning on page 17. Cover photo shows autonomous haul trucks at Rio Tinto's iron ore mine in Australia. Photo courtesy of Rio Tinto.

This month exclusively on MiningEngineeringMagazine.com:

Web exclusive:

Cowal gold mine; Success in mining through saprolites - a case history
by Ron Crouse and Shane Wright

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What does the future hold for coal?

Recent rules will impact the US coal industry

J. Steven Gardner
2015 SME President

As most people in the mining industry know by now, July 2015 was a portentous month for coal. Significant federal rules affecting both coal production and use were released — one a package of regulations from the U.S. Environmental Protection Agency (EPA) limiting greenhouse gas emissions from coal fired power plants, better known now as the Clean Power Plan (CPP), and the other, from the Office of Surface Mining (OSM), a proposed rule to limit environmental impacts to streams from coal mining, or the Stream Protection Rule (SPR). These rules are quite voluminous — in excess of 5,000 pages — and will certainly further curtail the nation's use of coal.

These regulations will have an impact on an industry that is already reeling from a historic downturn. We all know the various causes of the downturn: the very real "war on coal"; other environmental regulations from the federal government; the slowdown in the global economy; competition from cheaper natural gas and also growing competition from subsidized renewable sources. In a nutshell — the energy landscape is changing dramatically, and these recent regulations will accelerate those changes.

I'm a history buff, and when I look at the dramatic changes that took place in the global economy and political landscape, social institutions, technology, etc., during the first decades of the 20th Century, I'm reminded that it would be naïve to expect anything less than significant changes for us in the first decades of the 21st Century. Our energy landscape will not be the same one that drove our nation during the last 100 plus years. At the same time, it's little solace when you're in the middle of it, and believe as I do, that a more gradual transition in our energy economy would be more prudent, and that market forces should be the primary driver of these changes.

As the EPA itself acknowledges, even without regulations on carbon dioxide emissions, the energy landscape is transforming as a result of technological and market forces — many of the forces we did not fully anticipate. This point is especially important. The EPA's rules on greenhouse gases are energy policy — not environmental policy. A statement from Federal Energy Regulatory Commissioner (FERC) Commissioner Tony Clark captures the frustration of many people with EPA's climate rules. His colorful argument is that no one should believe the emissions-cutting regulation in the CPP will be straightforward. "Whatever EPA believes are the environmental benefits of this regulation, it cannot be said that it will be easy or inexpensive. Such is the stuff of unicorns and leprechauns," he said in a statement. He went on to say, "For if EPA's energy vision was the most reliable and affordable means of providing power, we would not need the rule. Engineering experts, markets, utilities and their regulators would already be choosing these resources without EPA dictates."

What do the greenhouse gas rules really mean for coal? Any rule that favors renewable energy resources, natural gas and nuclear over coal is going to further erode the nation's coal industry. How quickly existing coal plants will close as a result of the existing source rule will depend on how individual states write their compliance plans. The final rule has placed much more

(Continued on page 16)

Safety share: In mining, what we mean by being "safe at work" is embodied by the H.L. Boling term "safe production." This includes everyone from the front office staff to the working-face miners to the contractors. In fact, at many operations, mining and safety are reaching consonance; that is, we don't do any task without consideration of safety… ever. So safety has become very much a part of not only our mining vernacular, but how we actually think of mining.

So what happens at home? Do you consider safety implications when doing your chores at home? Do you communicate the expectation to others that safety must be considered prior to initiating: mowing the grass, cleaning the gutters, working on the car, etc.? Are you leading by example at home like you consistently do at work? The top five causes of accidental death at home involve: falls, poisoning, fire/burns, airway obstruction and water (Home Safety Council). Set the safety expectation with your family and neighbors. Make safety a habit…all the time.

Provided by Eric Lutz, Chair, SME Health and Safety Division

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MSHA increases enforcement,outreach efforts

THE U.S. MINE Safety and Health Administration (MSHA) has called for more enforcement in the wake of three mining fatalities on Aug. 3. MSHA said it would step up its enforcement efforts after separate accidents at mines in Nevada, North Dakota and Virginia on Aug. 3 left three miners dead. MSHA said it will also increase its outreach and education nationwide.

In a conference call with industry stakeholders, Assistant Secretary of Labor for Mine Safety and Health Joseph A. Main expressed his concern over the alarming number of recent deaths. "In the past month alone, there have been five fatalities in the metal and nonmetal industry. Not since 2002 have three miners died in a single day in this mining sector. We cannot — we will not — accept this turn of events. We extend our deepest sympathies to the families of the miners who died in these tragic accidents," said Main.

Main announced that, beginning the week of Aug. 10, the agency will begin beefed-up inspections with a focus on violations commonly associated with mining deaths, and federal inspectors will emphasize "walk and talks" with miners and operators to disseminate information on fatalities and best practices for preventing them. MSHA coal mine inspectors, along with training and educational field personnel, will be tapped to assist in the initiative.

"We will need everyone's cooperation with these efforts to reverse the trend in mining deaths," said Main. "Our miners deserve nothing less."

In 2014, there were 29 deaths at metal and nonmetal mines and 15 to date this year. "MSHA inspectors will intensify their examination of the types of conditions leading to these deaths and take appropriate enforcement actions," said Main.

Recent fatalities and other accidents at metal and nonmetal mines suggest that miners would benefit from rigorous workplace examinations conducted by experienced and trained examiners. On July 22, MSHA published a program policy letter clarifying the requirements for workplace examinations. The requirements include:

Mine operators must examine each working place at least once each shift for conditions that adversely affect safety or health.

- The examination must be conducted by a competent person.
- A record of the examination must be maintained and made available for review. ■

NMA challenges Clean Power Plan

THE NATIONAL Mining Association (NMA) requested the Obama administration to stay its climate change rule for power plants pending judicial review.

The Washington D.C.-based national trade organization said the new rule from the U.S. Environmental Protection Agency (EPA) will increase energy costs.

"EPA's final Clean Power Plan reflects political expediency, not reality for supplying the nation with low cost reliable power," NMA President and CEO Hal Quinn said in a statement. "Left in place are targets for replacing affordable energy with costly energy."

The tougher climate change rule for power plants demands that generators cut their carbon dioxide output 32 percent in the first-ever limits on the pollutant.

The historic regulation from the EPA is the main pillar of President Obama's climate agenda. It is the biggest piece of his drive to create a legacy and go down in history as the first United States president to take comprehensive action against climate change by cutting emissions of greenhouse gases such as carbon dioxide, *The Hill* reported.

Under the rule, the EPA is asking states to formulate plans to reduce carbon emissions by 32 percent from 2005 levels by 2030. Plans are due in September of 2016, but states that need more time will be able to request a two-year extension for final plan submissions. Compliance would begin in 2022 instead of 2020 and emission reductions would be phased in gradually up to 2030.

In a letter to EPA Administrator Gina McCarthy, the NMA said the climate change rules are likely to be reversed on appeal, because Congress did not give the agency the power to restructure how the nation produces and consumes electricity.

"Congress did not even give the Federal Energy Regulatory Commission, much less EPA, that power," the letter said. "Instead, Congress, in the Federal Power Act, preserved states' inherent power over electric utility resource planning and development."

The NMA said the EPA rule would cripple domestic coal production and eliminate thousands of mining jobs. The group is pushing the agency to stay the effectiveness of the rule until after it's litigated on its merits.

"All of this time, effort, money and controversy will be for naught if the rule is overturned," the NMA said in its letter to the EPA. "Worse, changes to the grid that states would not choose to make absent the rule will be locked in if a stay is not issued."

NMA wasn't the only industry group voicing its opposition to the rule. The National Association of Manufacturers (NAM) said it is keeping all options on the table, including litigation, to protect manufacturers' ability to compete in the global marketplace.

The U.S. Chamber of Commerce said it's also considering litigation to stop the rule it's calling "an EPA regulatory power grab," from taking effect. ■

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Uranium company files suit to mine;
Virginia Uranium challenges state for right to mine deposit

VIRGINIA URANIUM filed a federal lawsuit against Virginia Gov. Terry McAuliffe for the right to mine the largest uranium deposit in the United States.

The lawsuit thrusts the controversy back into the spotlight for the first time since McAuliffe (D) promised nearly two years ago to veto legislation allowing mining, *The Washington Post* reported.

Virginia Uranium owns a deposit of 54 kt (119 million lbs) in southern Virginia. The company argues that the uranium could fuel U.S. nuclear power plants for two years and that federal — not state — agencies have jurisdiction over the activity.

Supporters of uranium mining said it would bring jobs and tax revenue to an economically struggling region, while opponents say the potential harm to drinking water and the environment isn't worth the financial boost.

Walter Coles Sr., president and chief executive of Virginia Uranium, said the suit came after an expensive eight-year battle to persuade the state to repeal the ban and develop regulations.

"We do not come to this point lightly," Coles said in a statement. "We had hoped that our steady progress and good faith cooperation with commonwealth legislators and officials would continue under Gov. McAuliffe's administration. But that was not to be."

Coles said he interpreted McAuliffe's veto threat as an "ultimatum" that gave the company "no course but to seek a legal resolution."

A few days after winning election in 2013, McAuliffe said he would not support uranium mining and was not convinced that it is safe for drinking water, according to *The Virginian-Pilot*. The issue is particularly contentious in Virginia Beach and the surrounding area, which relies on drinking water from a lake downstream from the deposit.

The lawsuit says extracting the material domestically would reduce dependence on Russia, which supplies about one-fifth of the uranium used in U.S. nuclear power plants.

The company says it controls 1,400 ha (3,500 acres) atop the largest known uranium deposit in the country — and one of the largest in the world — with a market value of $6 billion.

Besides McAuliffe, the suit names as defendants 10 state officials including Maurice Jones, Secretary of Commerce and Trade, and Molly Ward, Secretary of Natural Resources.

Virginia Uranium argues the state won't develop mining regulations because of environmental and radiological safety concerns over the processing of uranium ore and storage of radioactive waste. The company says working out those issues is up to the U.S. Nuclear Regulatory Commission, not the state.

"The commonwealth cannot refuse to develop state mining regulations based on concerns over activities that are permissible under federal law and under the clear jurisdiction of the federal government," Charles J. Cooper, the attorney who filed the suit, said in a statement.

The Washington law firm of Cooper & Kirk filed the suit in U.S. District Court for the Western District of Virginia in Danville. ■

Newswatch contents

Carmichael Mine approval
overturned by Australian court

A FEDERAL COURT in Australia overturned the approval for Adani's giant Carmichael coal mine and rail project in Queensland that was originally granted by the Australian government in 2014. The government cited environmental concerns as the reason for pulling the permit for what would have been one of the largest coal mines in the world.

Critics had challenged the decision to approve the mine in the Federal Court of Australia because of a range of environmental concerns.

In issuing its decision to revoke its approval, the court said that the environment minister had failed to heed advice about threats to vulnerable animal species, *The BBC* reported.

The decision means the mine could not legally operate until fresh approval was granted, according to Sue Higginson, the principal solicitor for the Environmental Defenders Office (EDO) in New South Wales (NSW).

The EDO challenged the government's approval of the mine on behalf of the Mackay Conservation Group.

There were concerns a proposed coal port for the mine would damage the Great Barrier Reef.

The conservation advice describes the threats to the survival of two species

(Continued on page 14)

Royal Gold strikes streaming deal;

Deal will team company with Barrick Gold

ROYAL GOLD INC. has agreed to pay Barrick Gold Corp. $610 million up front and additional payments over time for a share of the gold and silver produced by a mine in the Dominican Republic under a streaming deal agreed to by the two companies, *The Denver Business Journal* reported.

Denver-based Royal Gold will get a percentage of the gold production from the Pueblo Viejo openpit mine attributable to Toronto-based Barrick's 60 percent stake in the mine. (Vancouver-based Goldcorp owns the remaining 40 percent.)

In exchange for an upfront payment of $610 million, Barrick has agreed to supply Royal Gold with 7.5 percent of Barrick's share of the gold produced at Pueblo Viejo until a cutoff of 28 kt (990,000 oz) is reached, and 3.75 percent after that.

Also, Barrick will supply Royal Gold with 75 percent of Barrick's interest in the silver produced at Pueblo Viejo, based on a fixed 70 percent recovery rate, until 1.4 kt (50 million oz) have been delivered, and 37.5 percent after that.

Royal Gold also will pay Barrick 30 percent of the spot price per ounce of gold and silver until certain thresholds are reached, and then 60 percent of the spot price.

Barrick has been selling off assets and is trying to reduce debt in the face of slumping precious metal prices, *Bloomberg* reported.

"This agreement adds revenue from yet another high quality, long-lived asset to Royal Gold's portfolio and, when coupled with three other transactions in recent months, significantly diversifies our revenue sources," said Tony Jensen, Royal Gold's president and CEO. "It provides our shareholders with substantial resource conversion optionality and a favorable entry point in the commodity cycle. Opportunities of this caliber and magnitude are rare and we are pleased to partner with Barrick on this world-class operation."

Royal Gold announced that it had agreed to pay New Gold Inc. of Vancouver $175 million for a percentage of production from the Rainy River gold and silver mine in Ontario, Canada. ■

MSHA says coal dust rule is working;

99 percent of industry is in compliance with year-old rule

ONE YEAR AFTER the implementation of its coal dust rule, the U.S. Mine Safety and Health Administration (MSHA) announced that 99 percent of the mining industry is in compliance with the rule.

MSHA's final rule, which took effect in August 2014, reduced the allowable exposure from underground mines to 1.5 milligrams per cubic meter (mg/m^3), down from the 2 mg/m^3 standard that hadn't changed since the 1970s.

MSHA's Assistant Secretary of Labor Joseph Main said 99 percent of the mining industry is complying with the rule.

Of nearly 62,000 dust samples taken from surface and underground coal mines from Aug. 1, 2014 to the end of July 2015, the administration said only 1.1 percent of samples exceeded the dust concentration limits.

"This is good news for our miners," Main said.

MSHA took 30,000 samples at 330 underground and approximately 900 surface mines and facilities. The rest were taken by coal mine operators, *The Hill* reported.

Part of DOL's 2009 End Black Lung — Act Now! campaign to raise awareness for the deadly disease that's caused or contributed to 76,000 coal miner deaths since 1968, the rule is now entering its second phase.

Starting Feb. 1, 2016, mining operators will be required to monitor underground respirable coal dust concentrations with continuous personal dust monitors (CPDM). The new devices will provide miners with real-time data on dust concentrations.

With the CPDMs, Main said miners will be able to not only measure the dust but assess where it's coming from and either choose to manage it or move somewhere else within the air stream.

While this rule is advancing to further protect coal miners, the agency has yet to finalize its rule to protect miners from silica dust, which can cause an irreversible lung disease known as silicosis.

"The rulemaking process is not expedient in how it's done," Main said. "We proposed this rule in October 2010 and issued it in May 2014."

As for the final silica dust rule, he said, the agency is still working on it. ■

Letter to the editor:

What should be done to hold the EPA accountable for mine water spill

To the Editor:

I have been reflecting on the Environmental Protection Agency (EPA) disaster in causing and its handling of the Gold King Mine water spill in Colorado. This event is now impacting the Colorado River ecosystem as well as commerce and agriculture in the immediate area as well as miles downstream. Importantly, the incompetence of EPA employees has blemished a crown jewel of the United States and a World Heritage Site, the Grand Canyon.

When the private sector negatively impacts the environment, a government agency steps in to evaluate its impact, guide its remediation and levies fines upon the offender. When the oversight agency is the culprit, what should be done?

The government cannot fine one of its agencies, and even if it could, the fine is ultimately paid using taxpayer dollars, so that is an untenable solution. Yet, there should be consequences imposed upon the EPA as the main actor in this environmental disaster. May I suggest a three-part remedy to this conundrum?

1.) Current funds used by the EPA to clean up and monitor this situation cannot be derived from new Congressional allocations of taxpayer dollars. The funds for these purposes are to be sourced by re-allocating dollars already budgeted to the agency. They should derive from current EPA budgets for overheads, research projects, new projects and areas currently viewed as EPA over-reaches as it tries to expand its authority.

2.) In place of imposing a "fine" on the EPA, for the next five years, the agency must work within a budget that is equal to its 2015 budget, with a significant deduction. Congress nor the EPA cannot expand the budget in any way: not by requesting funds for new projects, not by inflation or cost of living increases, etc. In addition, the full cost of the clean-up, including the value of the lost economic activity in impacted counties of Colorado, New Mexico, Utah and Arizona, is to be deducted from the budget and proportionally distributed to these counties and states each year during this timeframe in order for their businesses and agriculture to recover from the disaster.

3.) For the next 12 months the EPA will place 60-second public service announcements at least twice per week on each of the four main television networks: during the evening news hour and in prime time during which it acknowledges that the agency is at fault for the disaster, indicates that the mining industry is not cuplable for the event, and provide updates on its cleanup effort.

Lastly, a few jobs must be lost by those that were directly responsible for the activities, as well as their upline supervisors who approved of the plan and budget to carry out this ill-fated project.

The EPA must accept to the consquences of its misguided actions in this case, and be reminded not to overstep its mandates going forward. I believe that this three-point program will accomplish these requirements. Other government agencies should also take note that they will be held accountable for their miscues by the taxpayers as well. ■

Robert W. Schafer
Salt Lake City, Utah

Navajo Nation to sue EPA over spill;

Spill affected three states and the Navajo Nation

THE NAVAJO NATION, which along with Colorado, New Mexico and Utah, have been affected by the spill of 3 million gallons of tainted water from the Gold King Mine, was the first entity to announce that it intends to take legal action against the federal government for the spill.

The U.S. Environmental Protection Agency (EPA) reportedly caused the spill while it was working to close the mine when it breached a wall.

CNN reported that several political leaders have expressed outrage at the EPA spill and declared states of emergency. The spill will have a destructive impact on the ecosystems fed by the San Juan River that the Navajo culture depends on, Navajo Nation President Russell Begaye said.

"They are not going to get away with this," Begaye said. "The EPA was right in the middle of the disaster, and we intend to make sure the Navajo Nation recovers every dollar it spends cleaning up this mess and every dollar it loses as a result of injuries to our precious Navajo natural resources."

Begaye also instructed the Navajo Nation Department of Justice to take action against the EPA.

The EPA said it is helping provide water delivery to areas where water sources are contaminated, and the Navajo Nation utility company is sourcing its water from wells not affected.

"Navajo officials have reacted quickly, assessing their well fields and drinking and irrigation water intake systems and issuing a precautionary 'do not use' public service announcement regarding water from potentially impacted sources," the EPA said in a statement. ■

Carmichael Mine: Australian coal mine delayed again

(Continued from page 10)

found only in Queensland, the Yakka Skink and the Ornamental Snake, Higginson said in a statement.

"The law requires that the minister consider these conservation advices so that he understands the impacts of the decision that he is making on matters of national environmental significance, in this case the threatened species," she said.

The Department of Environment said in a statement that reconsidering the decision would not require revisiting the entire approval process.

"Without pre-empting a final decision about the project, the Department expects that it will take six to eight weeks to prepare its advice and the supporting documentation, and for the Minister to reconsider his final decision," it said.

The development is the latest in a string of delays faced by Adani, which has spent A$1.2 billion on the first stage of the mine, rail and port project opposed by green groups.

Adani, which has struggled to get financial backing for the project, had also won earlier approval to build a new coal port terminal on the Queensland coast to support exports from the mine.

In a statement, the company said it was regrettable "a technical legal error from the Federal Environment Department has exposed the approval to an adverse decision."

"Adani will await the Minister and his department's timely reconsideration of its approval application ... Adani is confident the conditions imposed on the existing approval are robust and appropriate," it said.

The project would have dug up and exported about 60 Mt/a (66 million stpy) of coal, mostly to India.

Environmentalists and reef scientists said work on the port could damage the nearby Great Barrier Reef.

Situated in the Galilee Basin in the central Queensland region, the Carmichael project would have included opencut and underground mines.

There were concerns also the mine, which would require about 12 billion L of water every year, would drain ground water supplies in the Galilee Basin. ■

Conflict minerals regulation struck down;
US Court of Appeals rules companies are protected by free speech

A REGULATION that would require companies to disclose if their products contain conflict minerals was struck down for a second time by a U.S. Appeals court. The 2-1 ruling from the U.S. Court of Appeals for the District of Columbia declared that the U.S. Securities and Exchange Commission's (SEC) effort to force public companies to declare whether their products may contain conflict minerals from a war-torn part of Africa violates their free speech, *Reuters* reported.

The SEC's conflict minerals rule is a provision mandated by the 2010 Dodd-Frank Wall Street reform law.

It requires manufacturers to conduct due diligence on their supply chains to try and track the origins of minerals including tantalum, tin, gold or tungsten to determine if they may have come from the Democratic Republic of Congo.

The measure is strongly backed by human rights groups who say such disclosures can help consumers and investors who wish to avoid any minerals that might have helped fund rebel groups.

But trade groups, including the National Association of Manufacturers, argued the rule was costly, burdensome and forced companies to publicly wear a scarlet letter if in fact the minerals did originate in a conflict zone.

The ruling still largely upholds the majority of the SEC's conflict minerals rules, which went into effect last year.

Companies still must conduct due diligence and file reports to the SEC with their findings, but they are not required to state whether or not the products are deemed conflict free.

The decision marks the second time that the three-judge panel has reviewed the regulator's conflict minerals rule.

In April 2014, the panel issued the same findings, but the SEC asked for a rehearing, after the U.S. appeals court later upheld another federal regulation requiring companies to label the origins of meat. ■

President's Page: Your donations can keep SMEF going strong

(Continued from page 06)

emphasis on renewable generation (utility scale renewable, not solar panels on houses) because the costs are reported to have dropped in recent years. Many states that have significant wind resources stand to gain. However, if you are a state that relies on coal-fired generation, and your ratepayers are assuming the costs of coal plant upgrades necessary to comply with other EPA regulations, you would like to be assured those coal plants can operate as long as possible.

The greenhouse gas rules are final rules. For existing power plants, states have until September 2016 to develop the compliance plans (extensions will be granted, but the substance of a state plan is due in September 2016). For new coal plants under the new source rule, partial carbon capture and sequestration would be required to achieve the carbon emissions threshold. This makes an argument for increased investment in technologies that can assure a place for coal in our energy future.

The air in the United States is dramatically cleaner today due to the technological solutions that have already been implemented on coal-fired power plants, industrial facilities and vehicles. We no longer hear of acid rain. That is a real success story. The rest of the world is still using coal and will continue to do so for many decades. EPA admits the climate benefits of the CPP are so insignificant that it has never bothered to measure them. The world would be a far better place if we would continue with the research and development of coal mining and utilization technology to export to the rest of the world to provide real environmental benefits. The CPP does not do that.

Also released in July was the OSM proposed new rules for regulation of coal mining. This voluminous rule has been characterized as a complete rewrite of the Surface Mining Control and Reclamation Act of 1977. The full impact of this proposed rule on the coal industry remains unknown. As this is a proposed rule, it is out for public comment. I encourage people to learn more about the rule. I will be doing the same.

Are these rules another nail in coal's coffin? They appear to belie a stated "all of the above" policy for the nation's energy portfolio. Given the Clean Power Plan is dramatically different in its final form compared to the proposed rule, and given the Stream Protection Rule is new to all of us, there will be quite a bit of scrutiny in the next few months regarding the impact of these regulations. There will also be many years of litigation surrounding both of these regulatory actions. There are some big unknowns facing coal and the rest of the mining industry in the next few years.

I want to remind you of John Marsden's column in the November, 2014 issue titled, "A convenient excuse: Politics of climate change is bad for the US economy, a common sense plan is needed." Marsden received some criticism for statements in his column for allegedly being a climate denier. Some also urged SME to take a stand on climate change — namely that we should officially admit that all climate change is a direct result of human factors. One of SME's roles is to speak out and defend the mining industry while finding solutions to the technical problems facing industry, including those that are attributed to climate change. As Marsden noted, climate change is a political reality. We have to develop our policies and programs to deal with those perceptions.

At the recent American Institute of Mining, Petroleum and Metallurgical Engineers (AIME) meeting, George Luxbacher, 2008 SME president and 2012 AIME president showed a statement from the metal plate once attached to the New York City office building housing AIME that I think sums up best SME's role:

"AIME seeeks to further the arts and sciences employed to recover the Earth's minerals and convert them to useful products. minerals are the sources of the materials man has used to build his world. They are basis of civilization and essential to the continuance of life as we know it."

Education sustainability

On a much more positive note, I want to personally congratulate the first recipients of SME's PhD Fellowships and Career Grants that were announced in July. We were very surprised with the overwhelming response we received from the call for applications. There were many excellent applications. To those not selected, please don't be discouraged. We wish we could fund more applicants. This is an ongoing program that will continue, so please keep those applications coming next year. Applications for 2016 open in December 2015.

Congressional Fellowship

I also want to congratulate Dr. Josh Hoffman, PE, SME's first Congressional Fellow who has accepted a full time position with the U.S. House Natural Resources Committee as Professional Staff on the Subcommittee for Energy and Mineral Resources and will continue to handle mining and mineral issues. I believe this underscores the success of this SME initiative by establishing a presence for mining on Capitol Hill. I also want to wish good luck to Kevin Ashley, PE our next Congressional Fellow who begins his term in September.

The SME Foundation and your dues statement

We have all said at one time or another; "I should contribute to the Foundation," and then never get around to it. The SME Board has approved a new program to make it easier for members to give to the Foundation and help support successful programs like the ones just mentioned. Your new SME dues statement will have an "Opt-Out" line for a $15 voluntary contribution to the Foundation. If 50 percent of U.S. members of SME contributed at least $15 to the SMEF, it would raise approximately $82,500 to fund critical programs. We hope that as people progress in their careers they will then consider increasing their contributions. Again, this is voluntary. If anyone feels they cannot make a contribution at this time, just opt out and deduct $15 from the amount shown due. ■

SME is getting a fresh look

What will the changes mean for you?

by Chee Theng, Technical Editor

The next time you log onto smenet.org, you might do a double take.

Yes, the web address is correct. No, you haven't been transported to a parallel universe. What you're seeing is your new portal to the SME member experience.

A complete redesign that put the focus on user experience has made the website more attractive, cleaner, more intuitive and quicker and easier to navigate, but the changes go well beyond the cosmetic. "One of our ambitions is to be a growth organization. Our objective is to have 20,000 members by 2020. Part of getting there is that we have to communicate with our members differently. We have to make it easier for our members to experience who we are, see what we have to offer," said SME's director of operations Tim Reagan. To do this, SME's inner workings have also received a total overhaul. Underlying the redesigned website is a new enterprise software called Personify that is specifically designed for the complex task of association management and has been built with an integrated, dynamic approach to how members join and renew their memberships, register for conferences, take part in events and become an active participant in the SME community.

"Implementing Personify is part of SME's long-term strategy and also part of the evolution of technology because we have outgrown our old iMIS database system, as happens with database systems," Reagan said.

So, with Personify in the back and the website on the front end, what possibilities lie ahead?

A look under the hood: Personify

What's new?

- Integrated and interactive platform.
- Instant response.
- Consolidated data.

Personify is the unseen agent. The only way you will have any idea that Personify is in place is from the integration it has with the new website. "With the website pulling data from Personify, we are going to be able to provide a better self-service platform for our members," said Paul Hoiberg, SME's IT manager.

Personify will put you in the driver's seat—you'll be able to renew your membership, survey your profile, enter updates, see your purchasing history, register for events. "All those functions that were disjointed in our old website will be seamless, and it will be easier for our members to get what they need done," Hoiberg explained.

Moreover, the response will be instantaneous. "You can become a member, buy a book, register for a meeting, all at once. Once you've finished all that you want to do, you close your session, and you're done," said SME's database administrator Jan Samuelson.

What excites Samuelson most of all is that the society's data will now all be consolidated in one place. "Instead of having to deal with spreadsheets in several different places to find the answer to one question, the information from every single SME department is in one system and accessible across the board," she said.

Internally, the software should help SME staff to be more efficient in handling tasks such as processing memberships, subscriptions and registrations and managing events and exhibits, freeing them up to have more touch points with stakeholders, be they members, nonmembers, exhibitors, subscribers or authors, and able to service their needs faster and more effectively, Hoiberg said.

An enhanced user experience: smenet.org

What's new?

- Quicker and easier navigation.
- Brighter and uncluttered design.
- User-centric sections.

"Our new website caters more to how our members think and how they want to interact with us, as opposed to our just saying what goes in and where," said Nicole Bencomo, SME's web content administrator. "The dynamic has changed. It is no longer just a repository but more of a destination site for our members and our customers."

To make this happen, the website was redesigned to make navigation easier and more intuitive, using bright and uncluttered pages, clearly legible fonts and a structure based on "mega menus," which display your navigational choices all at once on one big panel, eliminating the need to scroll. Gone is the confusing, convoluted list of updates on the homepage, replaced by a five-section panel whose contents will be rotated weekly to give an at-a-glance overview of the most-current activities, products, news and other offerings.

Bencomo also pointed to a shift to a member-centric layout so that members can easily locate the information they are seeking. "Our goal is that it shouldn't be more than one or two clicks away," she said. The site is divided into five main member-focused sections: About SME, Membership, Events & Professional Development, Publications & Resources and Students.

Under the new system, your email address will be your username for login. You will need to reset your password—just follow the instructions.

Explore when you log in to renew

Membership renewal for 2016 is fast upon us. "Log in when you renew your membership, update your profile and tell us what is most important to you," Reagan said. "As director of operations, one of my goals is to reach members with products that are relevant to them.... With your help, we can now start to talk to you specifically about things that matter to you, instead of sending messages out en masse to the 'generic SME member'."

Currently in soft launch phase

As with all projects involving huge amounts of data, the transition to the new digital platforms has been a massive endeavor. Moving the existing database content of a decades-old international society with more than 15,000 members to the new system involved a discovery phase of close to six months to make sure that all stakeholders' needs were met, followed by an implementation phase that included conversions, probably the most tedious part of the equation. "We're talking about managing more than 150,000 name records, over a million financial transactions," said Hoiberg. Greatly complicating matters was the fact that data were being pulled from a variety of systems.

The website is now in its soft launch phase, and some areas will not be fully functional as the transition is being finalized, but you will be able to log in and browse. Positive comments, constructive criticisms and feedback are welcome. "The website should be for the members, the way the members want it, getting information in the manner they are accustomed to getting it. That's what we really want to provide. Hopefully, we'll be doing that over the next six months," Hoiberg said.

"It is important to understand that this is going be an evolutionary activity," noted Reagan. "As a staff, we are going to learn how to be effective with these tools. As members, you are going to learn how to take advantage of the opportunities that this creates. But it's going to take time. We're going to be a lot better on Day 366 than we were on Day 1, but we're still going to be learning and evolving. It's a two-way engagement, and a lot of feedback from our members is going to help us learn faster." ■

Your guided tour of smenet.org

Quicker and easier navigation

The key is the mega menu. When you hover your mouse over the top banner, all your navigational choices are visible at once, avoiding the need to scroll.

Brighter and uncluttered design

You spoke, we listened. The new website is bright and welcoming and reflects the dynamic society we are.

Five user-centric sections

Quickly find what you need under five main sections: About SME, Membership, Events & Professional Development, Publications & Resources and Students.

Weekly updates

There is always something new every week. Visit the site regularly to stay up to date with industry and society happenings.

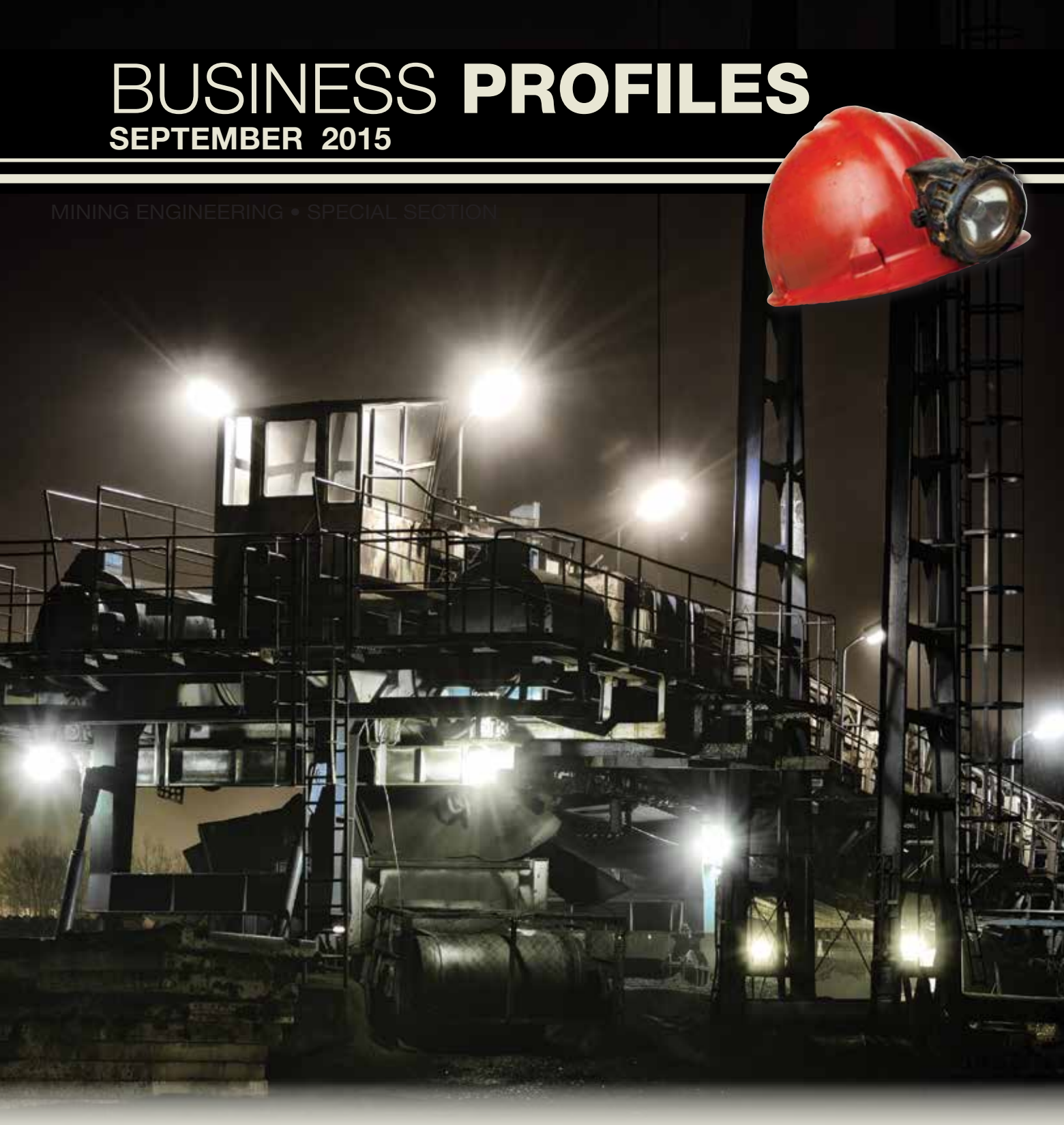
Integrated and interactive platform

Yes, it is a one-stop shop. Join, renew, register for meetings, sign up for events, buy a book, subscribe to a journal. You can do it.

Q: What is the best thing I can do to take advantage of the new digital platforms?

A: Update your profile. Tell us what you are interested in, cut out the noise and get only emails that are relevant to you.

BUSINESS **PROFILES**
SEPTEMBER 2015



Makers of Mining History

Mining history is made by the investment of companies worldwide that dedicate their efforts and vision to the advancement of mining everywhere.
SME and *Mining Engineering* acknowledge these companies that demonstrate a continued focus on providing the world the best in mining technology, products and services.

A special advertiser-sponsored advertorial section

Liebherr-Mining Equipment SAS

The mining equipment division within the Liebherr Group has achieved a high degree of trust as an active, accepted and valuable partner to the mining industry. The mining division enjoys the strengths and commitment of a family owned company.

Perfectly adapted to the demands of mining environments, Liebherr mining excavators and trucks work in tandem to provide customers with the remarkable availability and productivity. By maximizing payload while minimizing cycle time and cost, Liebherr high-horsepower equipment effectively moves more tons per hour, enabling mine operators to more quickly increase profits.

Liebherr-Mining Equipment Colmar SAS (France) product line includes mining and dredging excavators, powered by diesel engines or electric motors. Liebherr provides eight different hydraulic excavators models R 9100, R 9150, R 9250, R 9350, R 9400, R 995, R 996 B and R 9800 are available with bucket capacities from 7 to 47,5 m^3 (13 to 80 tonnes material weight) and engine power ratings up to 4,000 hp.

Liebherr Mining Equipment Newport News Co. (USA) manufactures diesel-electric mining trucks designed to handle payloads of up to 400 US tons. Versatile to handle both commodity and waste, these trucks work well in tandem with Liebherr excavators. Two models are available the T 264 (240 short ton, match with the R 996 B and R 9800) and the T 284 (400 short ton, match with the R 9800). With a focus on fuel-efficiency and reliability, customers can expect a high level of performance from these machines at the lowest cost per ton.

Liebherr's distribution is mostly conducted by its own sales and service organizations. This approach brings Liebherr companies closer to customer operations to better under-stand their individual needs and requirements. This also allows Liebherr's experienced engineering teams to incorporate customer feedback into their mining equipment design.

Productivity

Liebherr Mining Equipment enables superior productivity by loading and hauling maximum tonnage in the shortest amount of time. Innovative design of technologically-advanced equipment provides higher productivity at a lower cost. Employing the knowledge accumulated over the course of 60 years, Liebherr draws upon a wealth of experience while incorporating new technologies into their mining products. The result is evident in Liebherr's high-quality products that are distinctly efficient and highly innovative.

Low operating cost

Liebherr supports customers in achieving maximum profit-ability. There is a basic, fundamental understanding among Liebherr engineers that the mining industry needs products that provide excellent, consistent performance with minimum maintenance interruptions. Liebherr products are designed, manufactured, and continuously improved to offer high reliability and productivity at a lower operating cost.

Customer service

Liebherr builds more than just mining equipment; Liebherr also builds customer partnerships. By offering a complete range of services, and implementing a combination of scheduled, preventative, and planned maintenance, Liebherr allows customers to reach their goals at the lowest cost per ton. Product support personnel work with customers from the assembly of their equipment throughout its operating life. Liebherr understands the importance of proper service and support, and will be there for the life of the equipment.

Support is available for the following:

- Logistics
- Operator and maintenance personnel training
- Technical product support
- Rebuilt component exchange
- Maintenance management and on-site services

Safety and environment

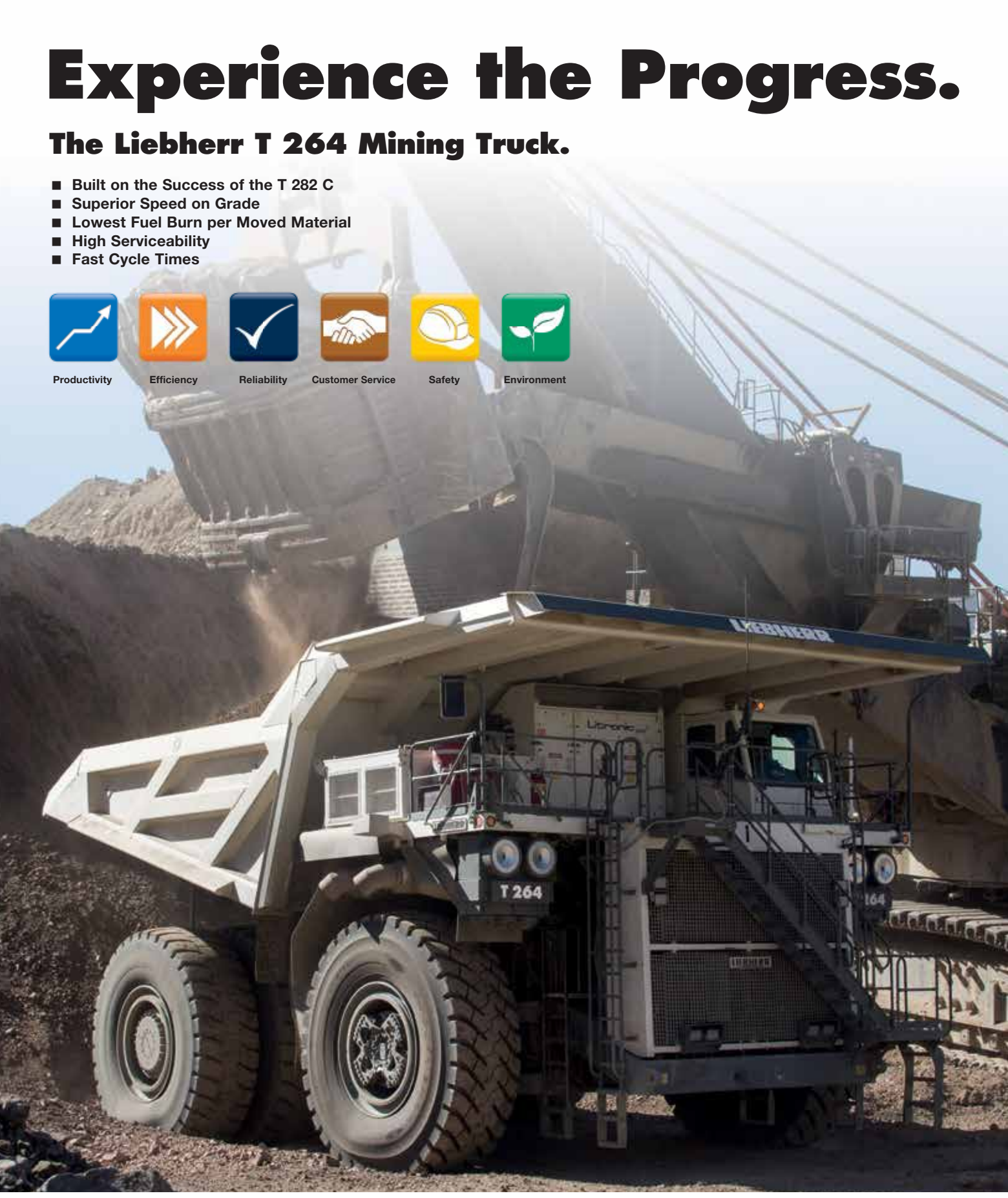
Mining demands an ever-vigilant focus on safety, and Liebherr strictly adheres to industry standards. Liebherr equipment is designed to diminish risk even under the most extreme mining conditions. The whole range of Liebherr mining equipment ensures uncompromising safety for operators and maintenance staff, with innovative technologies integrated into each product's design.

Experience the Progress.

The Liebherr T 264 Mining Truck.

- Built on the Success of the T 282 C
- Superior Speed on Grade
- Lowest Fuel Burn per Moved Material
- High Serviceability
- Fast Cycle Times

Productivity | Efficiency | Reliability | Customer Service | Safety | Environment



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LIEBHERR
The Group

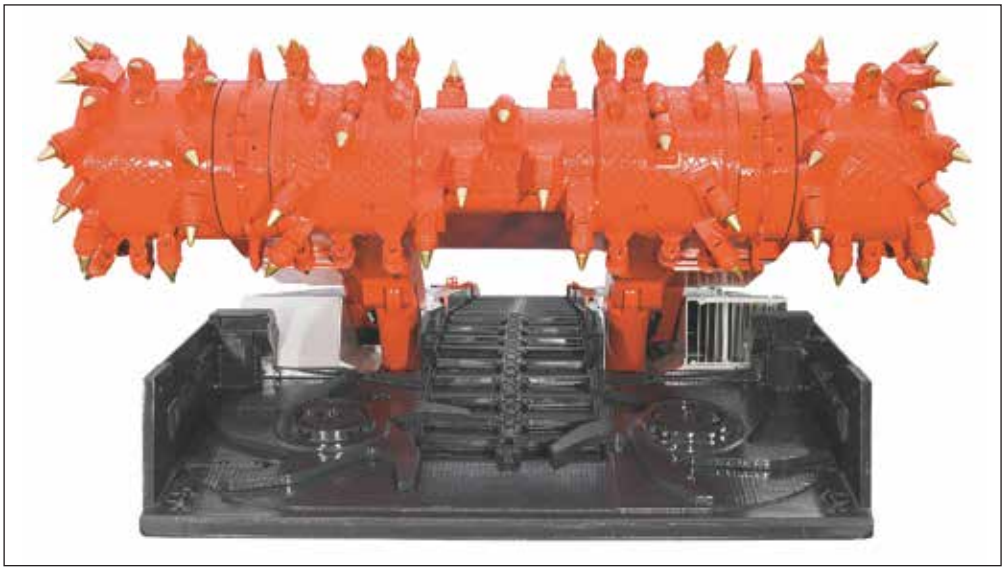
Sandvik Mining

The Sandvik MC350 continuous miner, for mid-size room and pillar applications, is the latest edition in the comprehensive offering of continuous miners from Sandvik.

The performance of Sandvik MC350 has been proven in extensive field tests in South Africa and, as all the continuous miners in the MC series, it offers high productivity and low cost of ownership.

Sandvik continuous miners, including MC250, MC430, MC470 and now MC350, satisfy all seam conditions in room and pillar mines. Segmented for low-, medium- and high-seam applications, the continuous miners are all equipped with the functions expected to ensure maximum productivity, reliability and minimum cost for any seam.

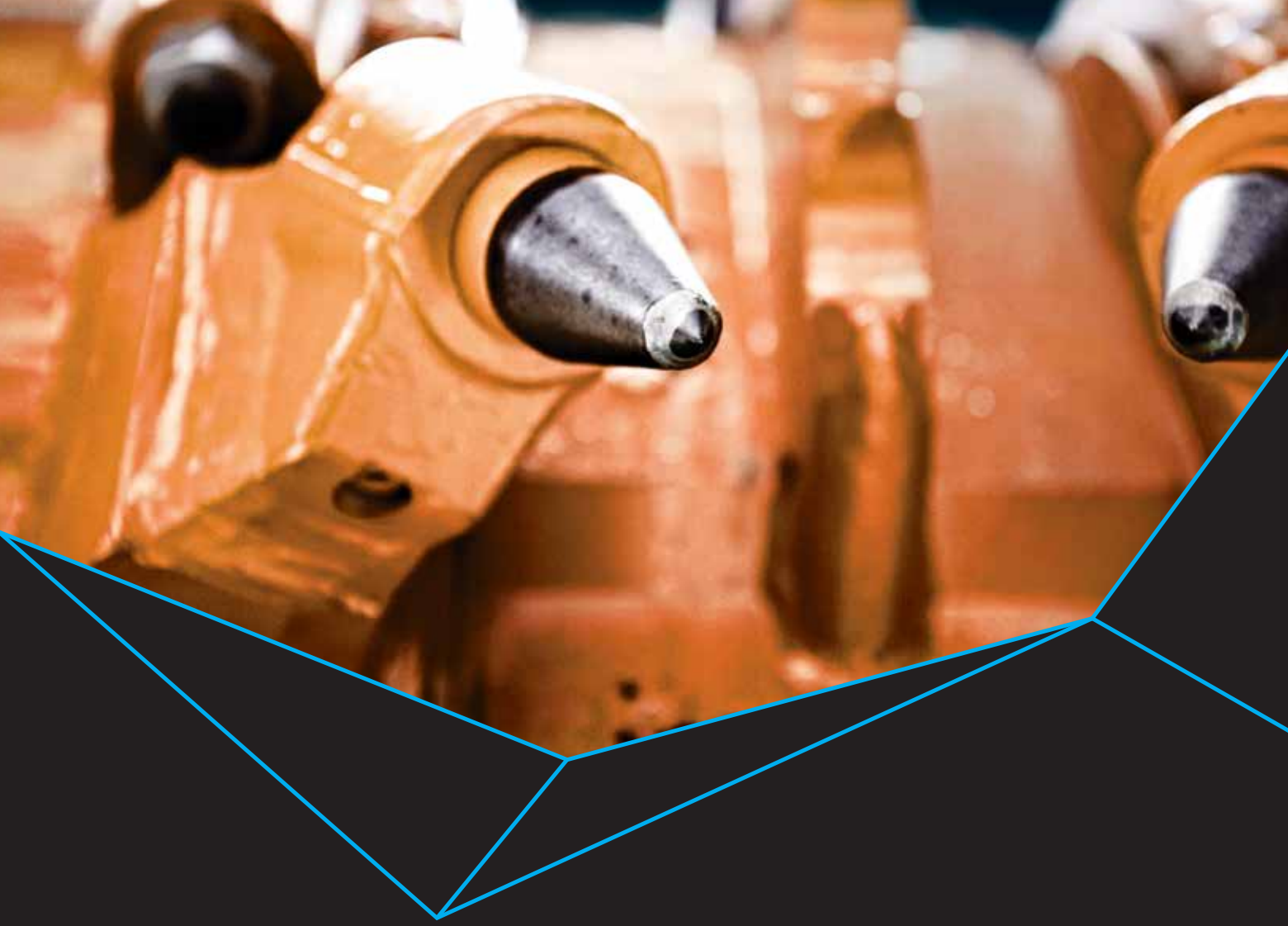
"By using Sandvik continuous miners our customers benefit from more cost efficient operations," says Bruno Reumueller, Product Line Management, Underground Coal and Minerals at Sandvik Mining. "Thanks to a higher weight class, shear-up capability and loading and conveying modules, our continuous miners can improve productivity by 10-20 percent compared to other continuous miners in their range. In addition, extended operating time between overhauls and a cost per ton that is equal or better than other continuous miners make this a very attractive offering."



The MC-series continuous miners are built using top-quality parts, sturdy, rugged structural components and boast a robust gearbox. Semi-automated and with a higher weight class, they offer a higher cutting rate and quicker loading time. Sandvik continuous miners can be fitted with a proximity detection system to improve safety. A health monitoring function also ensures advance warning of any problems before they arise.

"It's all about availability of the equipment and predictability in the operations, and part of that is also our complete parts and service offering", Reumuller says."Our service engineers ensure that our customers get the right parts, rock tools and service at the right time to ensure safe operation, low operating costs and long service life.

As a leading supplier to the mining industry Sandvik offer complete integrated solutions for continuous mining in room and pillar applications to make mining more productive and profitable including; bolter miners, continuous miners, roadheaders, cutter picks, shuttle cars, mobile bolters, conveying systems, feeder breakers, utility LHDs and QDS.



THE MECHANICS OF MINING MORE

Tough and uncompromising, Sandvik continuous miners are built to make the most out of your mine. Thanks to a higher weight class, shear-up capability and loading and conveying modules, they improve productivity by 10–20% compared to other continuous miners in this range.

The new range of Sandvik of continuous miners is specially designed to help you improve production in room and pillar mining of coal and industrial minerals. Built to extreme standards of ruggedness and reliability, these miners offer cutting, loading, and hauling excellence so that you can mine more coal and more minerals more often.

Discover the mechanics of mining more.

SANDVIK

MINING.SANDVIK.COM

Veolia - Creating Water Solutions for Mining

Veolia is committed to resourcing the world and is developing new ways of making water, this vital resource, available when and where it is needed. For over 160 years, Veolia has been helping cities and industries worldwide manage, optimize and make the

most of their resources, especially water.

Veolia understands the importance of water to the residents of cities and for industrial production. Resourcing the World defines our commitment to develop innovative systems that provide, protect and replenish natural resources. Our systems are designed to provide high quality water, treat and reuse wastewater, produce and recover energy, extract raw materials and capitalize on valuable byproducts.

- Process Solution Filtration
- Acid Mine Drainage
- Mine Dewatering
- Coal Pile Runoff
- Tailing Ponds Management
- Production Processes
- Byproduct Recovery
- Alkaline Mine Drainage
- Coal Prep Plants
- Process Water
- Boiler Feed Water
- Mobile Solutions

Advanced Sulfate Removal Process

Veolia's sulfate removal solution increases water recovery to >98%, recovers >95% of the aluminum-based reagent for reuse and produces clean water

effluent for discharge with <100 mg/l sulfate. This is achieved by a two-stage precipitation process that is enhanced by Veolia's proven, small-footprint MULTIFLO™ and Turbomix™ technologies.

Biological Selenium Reduction

Veolia's AnoxKaldnes™ MBBR technology is a high-rate, small footprint biofilm process that can handle high TSS concentrations in feed as well as large hydraulic variations. This system does not require back-washing and can operate with the same support material for over 20 years. The advantages of the MBBR process for selenium removal can provide cost savings and operation flexibility to a mine site.

SeleniumZero® Adsorption Process

Veolia has developed an easy-to-operate, cost-effective process that utilizes a proprietary Hydrex® adsorption media to remove selenium from mine water. Filtration is combined with an adsorption column containing a patented iron oxide-based media that consistently removes the most commonly occurring forms of selenium below the 2-µg/L detection limit. Ideal for direct removal of low selenium concentrations, SeleniumZero can also be applied as a polishing step following biological treatment.

Veolia
www.veoliawaterstna.com

WATER TECHNOLOGIES

LoSO4 – Sulfate Reduction Solution

New regulations that limit sulfates in surface water discharges along with increased interest in the reuse of mine water for beneficial purposes are drivers for seeking improved methods for sulfate reduction. Veolia's LoSO4 is an advanced sulfate removal process that meets regulatory standards while generating a clean water effluent for reuse or discharge.

To learn more, visit our website at: www.veoliawaterstna.com/LoSO4

Resourcing the world

VEOLIA

Turn-key Processing Solutions

Operational experience and a passion for performance distinguishes Turn-key Processing Solutions from other Engineering, Procurement, Construction and Management companies (EPCM) With more than 150 years of combined practical mineral processing & mining experience in house, the company provides a unique skill set to your team.

TPS has built it's reputation on providing performance based contracts with Guarantees. They make bold promises, assemble the cross functional expert teams to keep the promises and follow a process which provides reliability, predictability and accountability to every project.

Engineering:

TPS has a diverse engineering group located around the country to help serve clients various needs. The team of engineers work on: Plant Designs, Site Designs, Plant Flows, 3D Modeling, Automation, Capital Budgeting, Feasibility Studies and Mine Planning. Some of the areas of expertise include: process engineering, plant design, mechanical engineering, civil engineering, structural engineering, automation / electrical engineering and detailing. They use the latest technology to design, analyze and build the best system to meet each projects specifications. They have locations in Chicago, IL., Burlington, WI. Kansas City, MO., Nashville, TN., Atlanta, GA. The Engineering group works on anything from complete "Turnkey" projects to feasibility studies.

Procurement:

Proficient management is critical to the success of any project. While other firms have engineering, construction or manufacturing backgrounds, TPS has the full range of EPCM capabilities. Plus, our managers have proven track records in plant operations. Having a project manager who knows not only how to build plants but also how to operate them is a clear advantage. You will be able to start operating sooner and your overall operation costs will be lower.

Managing Success- at TPS they believe that success starts with people. Our experienced project managers have a well-earned reputation for completing projects safely, on time and on budget. All TPS project managers have a minimum of 20 years of experience and undertake the following:

- Define the complete scope of the project
- Create realistic time lines and Gantt charts
- Develop and execute a project plan
- Determine the capabilities of all of the required resources
- Directly manage all subcontractors
- Track progress of all project activities
- Develop and track budget versus actual costs
- Clearly communicate with all stakeholders
- Provide daily on-site support for the duration of the project
- Provide leadership throughout the project
- Execute the startup and commissioning process

Construction:

Promising clients Predictability, Reliability and Accountability – Safely was a driving force in the decision to start a construction company. Turn-key Construction Company, LLC has the same driving principles of delivering value and safety on every project. Our team of professionals have experience working on operating plants and carry that important operational background to the field on your projects. They are safety trained and have a good understanding on how the equipment operates.

Management:

With the operational experience TPS has it's a natural fit for the company to provide both short term and long term operational contracts. TPS is responsible to meet the performance requirements during the construction phase and then is responsible to drive in operational efficiencies for their clients. If a company has a need to mitigate risks operationally TPS has the ability to provide superior operational management that exceed your expectations.

Phone: 1-815-741-3760 www.gototops.com

TPS

PROVEN SOLUTIONS FOR YOUR MINERAL PROCESSING & HANDLING NEEDS

Turn-Key Processing Solutions has years of operational experience in mining in many different materials. We offer you expertise from the beginning of a project through operations:

- Feasibility Studies
- Capital Budgets & Operational Budgets
- Mine Planning
- Process Flows
- EPC (Engineer, Procure & Construction)

TPS is your best source of information and a great partner for opening a mine or modifying an existing mine.

WE DESIGN, BUILD AND CONSTRUCT PLANTS THAT PERFORM — WE GUARANTEE IT!

- Engineering
- Project Management
- Operations Management
- Process Improvement
- Procurement
- Consulting
- Construction
- Systems Integration
- Design Build
- Performance Based Contracts

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South African Explosives Manufacturing Plant Improves Uptime and Cuts Costs with NETZSCH Pumps

Pump downtime and serious maintenance problems drove a major manufacturer of commercial explosives for mining, quarrying and construction to seek a new pumping solution. This manufacturer was facing pump failure every 4-6 weeks with their existing ammonium nitrate emulsion manufacturing process pumps. The universal joint of the existing pump was failing, and the stator couldn't handle the heat in the emulsion production rig, which is housed in a shipping container.

The ammonium nitrate solution is pumped into a jet mixer, where it is fed oil and pumped into an emulsifier. The ammonium nitrate emulsion is subsequently pumped through a heat exchanger to drop the temperature before being pumped into storage silos for transport.

Even though the plant has an on-site maintenance and repair team, each of the frequent pump failures involved a 10-hour repair process.

NETZSCH Pump Provides 18-Month Uptime

To solve these issues, NETZSCH offered a NEMO® progressing cavity pump with an undercut rotor. This solution allowed the customer to pump at higher temperatures and overcome pressure losses through the exchanger.

With the installation of the NETZSCH progressing cavity pump in the explosive emulsion production process, this customer has gone 18 months without any maintenance problems or downtime. The NETZSCH pump also has allowed the customer to produce 30% more bulk emulsion in the same installation space while saving on energy costs.

"With the improved uptime, we are able to deliver more product per hour alongside problem-free pumping" Tryon Adam, a NETZCH representative in South Africa, said.

With the success of the NETZSCH progressing cavity pump on one of the plant's four explosive emulsion rigs, the customer is now in the process of changing out the three other emulsion production rigs for a total of eight NETZSCH progressing cavity pumps.

Eriez - Advanced Separation Technology

Eriez features separation, material handling and detection systems to concentrate magnetic ores, remove tramp metals and convey or feed heavy materials. Products include:

- Wet Drum Separators
- Magnetic Mill Liners
- Trunnion Magnets
- Magnetic Separators
- Metal Detectors
- Vibratory Feeders

Eriez Mining Equipment
Tel: 1-814-835-6000
www.eriez.com

Eriez Flotation has supplied over 800 flotation column systems worldwide for cleaning, roughing and scavenging applications in metallic and non-metallic processing operations, as well as modular column flotation systems for recovering bitumen from oil sands. Systems include:

- Flotation Columns & Cells
- Gas Spargers
- Mini-Pilot Plants
- Slurry Distributors
- Flotation Test Equipment

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Premier Pipe Systems Manufacturer for 90 Years

Since 1925, Naylor Pipe Company has been the premier manufacturer of Spiralweld pipe systems.

Naylor Spiralweld is available in diameters from 4" through 96" and wall thickness from 14 Ga. through 1/2" wall. The Spiralweld pipe is complemented with all types of fittings, fabrications to specification, and joint connections, including the exclusive Naylor Wedgelock Coupling, to complete your pipe system.

Naylor Spiral Buttweld pipe features two welds along the spiral seam. This creates a pipe structure in which the weld is as strong or stronger than the parent metal.

The Naylor manufacturing process creates a pipe that maintains an accurate diameter throughout its length. The uniformity of the pipe ends speed connection, whether mechanically coupled or welded.

Uniform wall thickness is assured because tolerances of steel strip are governed by the standards established by the American Iron and Steel Institute. In addition, the pipe is furnished in any required length with a cutting tolerance of plus or minus 1/8". In addition to carbon steel, spiralweld pipe can be formed from many steel grades, including abrasion resistant, weathering (A-588) and stainless.

Every length of Naylor Pipe is inspected and where required hydrostatically tested to applicable ASTM specifications. The

pipe is available in lighter weights than other pipe making it possible to save money, not only on initial cost, but also in transportation, handling and installation. By sizing the diameter of the pipe to the exact requirements, with exact lengths and factory-sized ends, the greatest economies can be realized.

Quotations are immediately available on inquiry.

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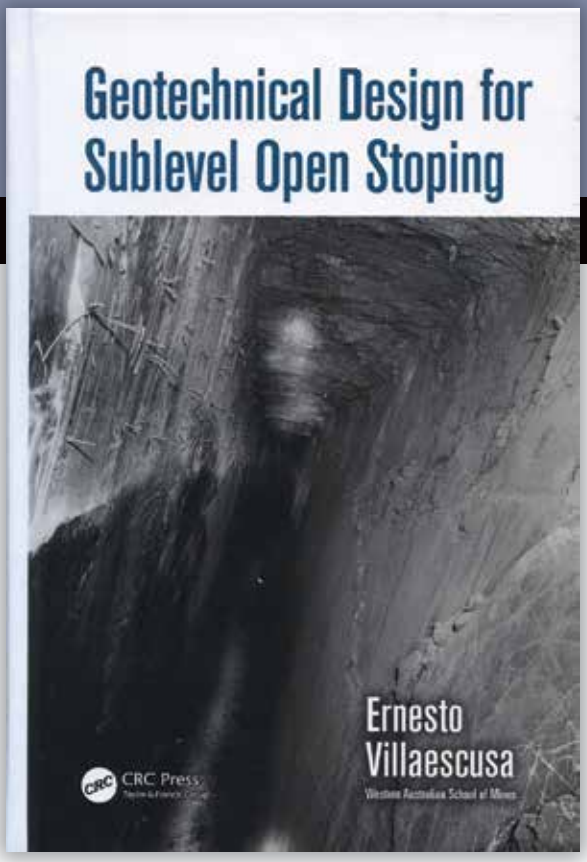

Geotechnical Design for Sublevel Open Stoping

By Ernesto Villaescusa

The first comprehensive work on one of the most important underground mining methods worldwide.

Geotechnical Design for Sublevel Open Stoping details the design and operation of sublevel open stoping, including variants such as bench stoping. The book discusses increases in sublevel spacing due to advances in the drilling of longer and more accurate production holes as well as advances in explosive types, charges, and initiation systems. Improvement in slot rising through vertical crate retreat, inverse drop rise, and raise boring are considered. Rock mass characterization is covered in detail because increases in sublevel spacing have preordained that larger, unsupported stope walls must stand without collapsing. Methodologies to design optimum open spans and pillars are described, as are rock reinforcement of development access and stope walls, and fill masses to support the resulting stope voids.

The text also reviews the sequencing of stoping blocks to minimize in situ stress concentrations and examines dilution control action plans and techniques to back-analyze and optimize stope wall performance.

Featuring numerous case studies from the world-renowned Mount Isa Mines and examples from underground mines in Western Australia, ***Geotechnical Design for Sublevel Open Stoping*** is a practical reference for industry and a specialized textbook for advanced undergraduate and postgraduate mining studies.

Contents

- Mining Method Selection
- Sublevel Stoping Geometry
- Planning and Design
- Rock Mass Characterization
- Span and Pillar Design
- Drilling and Blasting
- Rock Reinforcement and Support
- Mine Fill
- Dilution Control

Geotechnical Design for Sublevel Open Stoping

By Ernesto Villaescusa

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Development of mine haul road surfacing condition monitoring through digital image processing

by S. Hahn, S. Pastor and R. Thompson

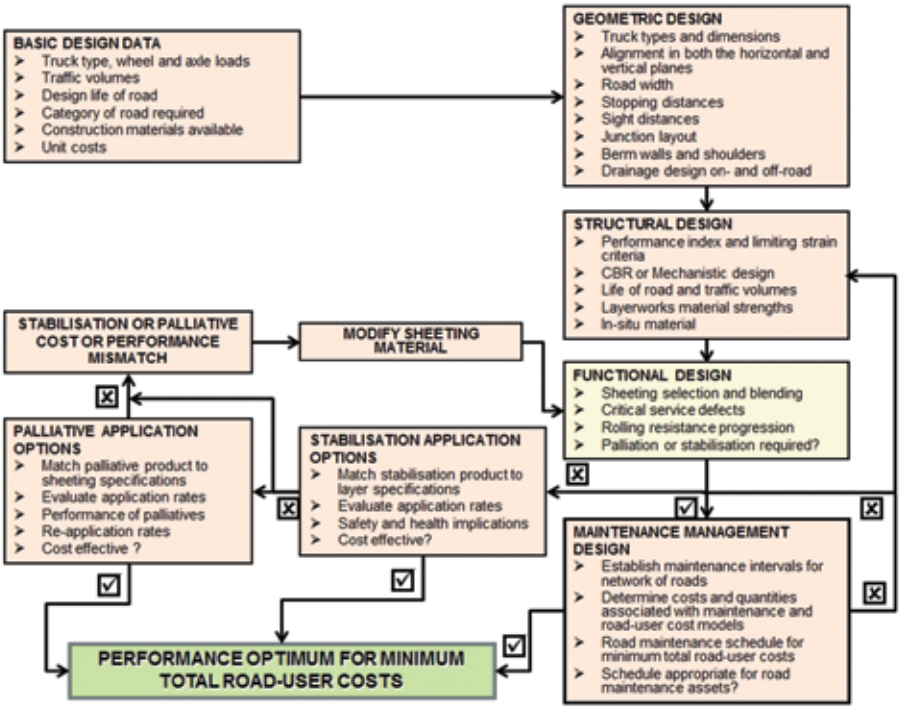
As the concept of autonomous haulage systems (AHS) moves from prototypes to production-ready applications, the operating performance of the haul road will become critical to the overall success of autonomy in mining. Deterioration in road performance will require remediation, human intervention and significant, albeit temporary, changes to operating procedures, to accommodate road maintenance. With autonomous trucks comes the opportunity to reduce road formation and operating width. This will, therefore, generate potentially significant reductions in stripping ratios and improvements to mine economics, but only if the design of the road, and its associated deterioration rate, is predictable and manageable, based on the materials used to construct the road and the maintenance interventions to be carried out on the road.

This article presents the assessment of a digital photogrammetric approach to the characterization of a mine haul road surfacing, or wearing course material. Design and maintenance parameters for these roads are currently determined partly from physical particle size distribution (PSD) assessments of 'in-road' material. However, this approach does not accommodate the need, nor leverage the benefits from, AHS. The digital imaging approach is assessed in this article, using two standard digital analysis software tools, together with in-service mine haul road wearing course samples and images that are analyzed to determine the applicability and reliability of the approach to deliver a real-time assessment of haul road surfacing conditions and thus to identify the road maintenance interventions required to address deterioration.

Enhancements in mine road design, construction and management for the past 20 or more years has largely been focused on short-term tactical needs. These improvements have not been matched by advances in the fundamental technologies that underpin mine road design and management and, although the quality of mine roads have probably

Figure 1

Typical integrated approach to road design.



S. Hahn, S. Pastor and R. Thompson, member SME, are graduate mining engineer, graduate mining engineer and professor, mining engineering, respectively, Western Australian School of Mines, Curtin Univ., Kalgoorlie WA, Australia, email r.thompson@curtin.edu.au.

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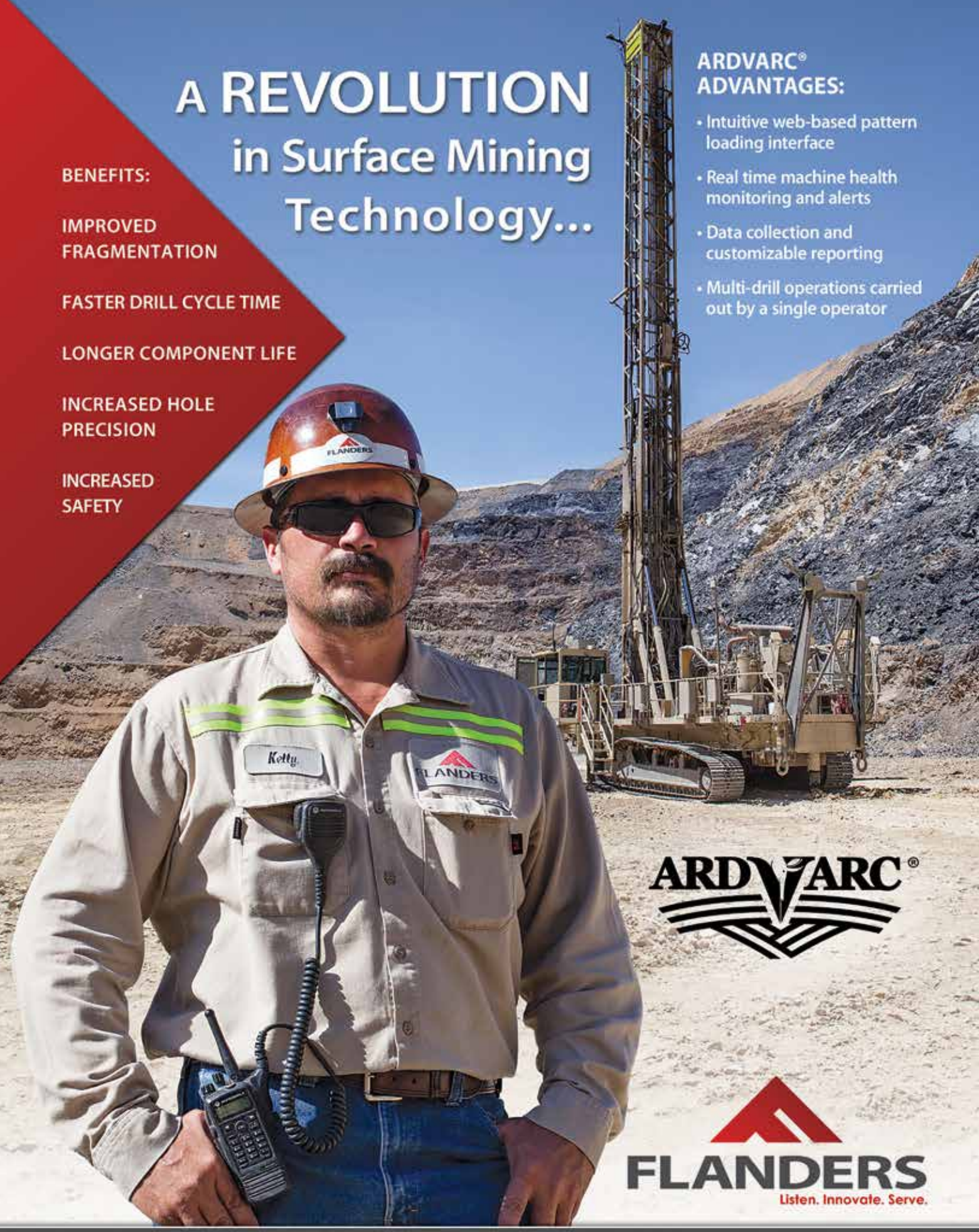

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increased, many of fundamental and longer-term performance issues have yet to be addressed.

With AHS's evolving from prototype to production applications, any decision to implement these systems in a mine requires a thorough evaluation of impacts, not only operational improvements, but the interconnectivity of this autonomy technology to other organizational processes. In developing an understanding, the full interactions that may affect autonomous truck behavior due to changes in various subsystems or external environments should be considered; haul road condition and operating performance being a key consideration. This is as true in autonomous as well as in conventional mine truck-based hauling systems where the mine haul road network is a critical and vital component of the production process.

In any truck-based hauling systems, underperformance of a haul road will impact immediately on mine productivity and costs. Operations safety, productivity and equipment longevity are all dependent on well-designed, constructed and maintained haul roads. The operating performance of a mine road can be subdivided into four distinct design components. When designing and constructing a haul road for optimal performance, these design components are best addressed using an integrated design and management approach, as shown in Fig. 1, based on the geometric, structural (layerworks), functional (wearing course or surfacing) and maintenance management components (Thompson, 2011)).

In this article, the functional design, or haul road wearing course (surfacing) material selection and operational performance is addressed. Initially, a brief overview of the role of surfacing material in road design and operation is presented, following which material selection and performance parameters are discussed. These parameters are typically determined from physical assessments of 'in-road' material. However, this physical 'in-road' approach does not integrate well with AHS's.

Therefore, a digital imaging approach has been proposed as an alternative to deliver a real-time assessment of haul road surfacing conditions, through PSD determination, by means of which haul road maintenance interventions required to address surfacing deterioration can be better predicted and scheduled.

Roadmap for haul road design and management in AHS. Figure 2 shows a summarized version of the broad generic challenges in road design development for AHS, from near-term 'tactical' considerations, through to long-term needs of a more strategic nature

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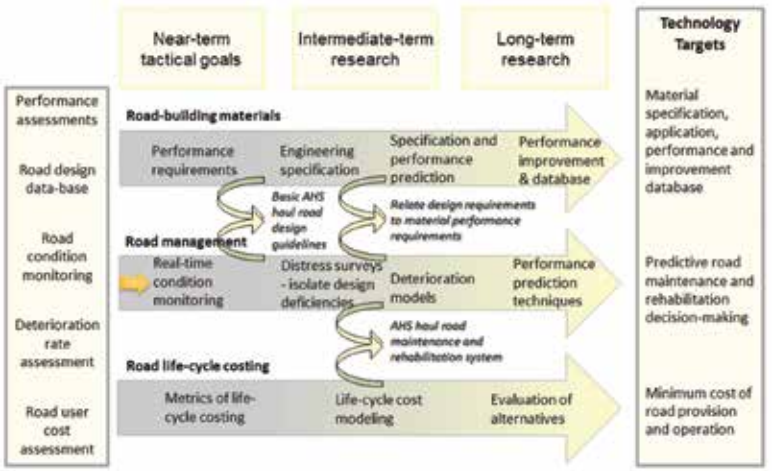
Figure 2

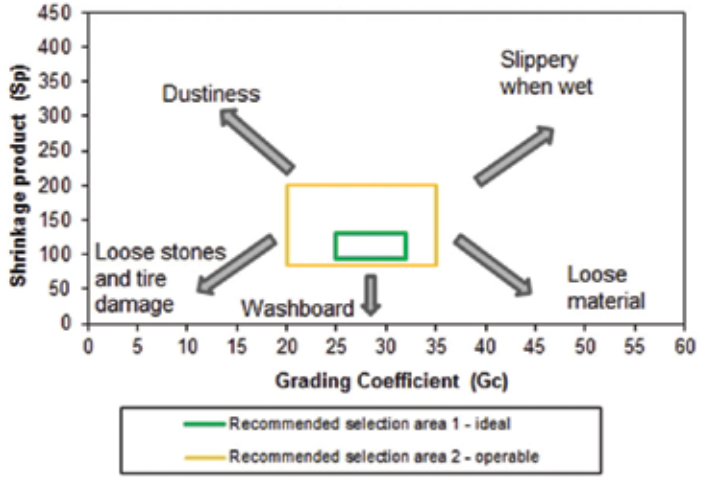
Roadmap for technology targets associated with autonomous haulage systems.



(Thompson, 2011). The first theme is materials for road construction, design requirements, engineering specifications, performance limitations and strategies for improvements or enhancement of inherently poor or unsuitable materials. Allied to the materials themselves is the road management system aspects of maintenance and rehabilitation; specifically the requirement to predict and manage road maintenance and rehabilitation activities within the constraints of an AHS – the digital imaging approach to deliver a real-time assessment of haul road surfacing. Finally, total road-user cost and life-cycle cost modelling combines with the other themes to enable an optimal design and operational strategy to be determined. Strategically, these themes would ultimately lead to a technology target specifying the road design requirements for autonomous vehicle themselves and, ultimately, to the autonomous mine in which road construction, management and maintenance or rehabilitation is achieved autonomously.

Figure 3

Haul road wearing course (surfacing) selection criteria.



Wearing course material selection

The functional design of a haul road is the process of selecting the most appropriate wearing course material or mix of materials that are commensurate with safety, operational, environmental and economic considerations. The most common wearing course material for haul roads remains compacted gravel or gravel and crushed stone mixtures. In addition to their low rolling resistance and high coefficient of adhesion/friction, their greatest advantage over other wearing course materials is that roadway surfaces can be constructed rapidly and maintained at relatively low cost. When local mine material can be used for construction, the costs are all the more favorable. This cost advantage is, however, not apparent in the long term if the characteristics of the wearing course material result in suboptimal functional performance.

By examining which wearing course material property parameters contribute to critical road performance defects, Thompson and Visser(2006) developed a specification for wearing course materials selection, based on a parametric relationship suggested in "Technical Recommendations for Highways" (CSRA TRH20(4)), but modified for mine road construction and operating parameters (which are very different from public, federal or state 'highways').

The specification is based on a wearing course material shrinkage product (Sp) and grading coefficient (Gc), defined below.

$$Sp = LS \times P425$$

$$Gc = \frac{(P265 - P2) \times P475}{100}$$

where:

LS = Bar linear shrinkage.

P425 = Percent wearing course sample passing 0.425 mm sieve.

P265 = Percent wearing course sample passing 26.5 mm sieve.

P2 = Percent wearing course sample passing 2 mm sieve.

P475 = Percent wearing course sample passing 4.75 mm sieve.

A suitable wearing course material can be determined from Fig. 3, in terms of the two parameters that describe the material; the shrinkage product (Sp) and grading coefficient (Gc). If the three most critical haul road defects are considered, it appears that mine road-user preference is for much-reduced wet skid

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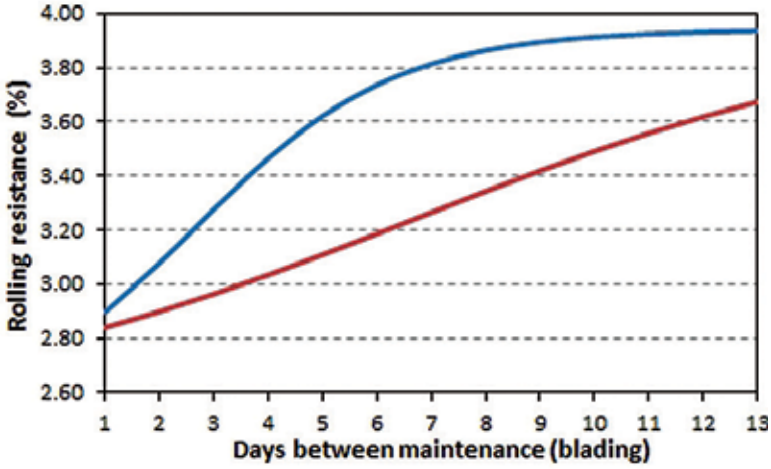
Figure 4

Impact of poorly selected wearing course material on haul road rolling resistance deterioration compared to well-selected material.



Rolling resistance progression (%)		
Modelled using;		
Vehicle speed (km/h)	40	
Days between maintenance	1-13	
Average daily tonnage (kt)	200	
Wearing course modelled as;	*New*	*Trafficked*
Plasticity Index	6	13
California Bearing Ratio	80	60
Grading coefficient	27	18
Shrinkage product	90	120

resistance, dust and dry skid resistance defects.

Figure 3 defines the focus point of the specifications to an area bounded by a grading coefficient of 25-32 and a shrinkage product of 95-130, in which the overall and individual defects are minimized (Area 1). Extending this region to encompass poorer (but nevertheless operable) performance enables an additional area (Area 2) to be defined. When the wearing course material or mix of materials is suboptimal, 'functional' defects rapidly form on the road, contributing to safety and road performance (high rolling resistance) problems, in addition to increased road maintenance activities. These suboptimal conditions may arise due to the progressive deterioration of the haul road under the action of traffic, the rate being dependent on the wearing course material properties and traffic speed and volumes on the road.

An example is shown in Fig. 4 of the rate of increase in rolling resistance as a function of the interval between road maintenance (blading/scraping) for a poorly selected wearing course material, subject to traffic volumes of 200 kt/d (220,000 stpd). If an improved wearing course material is defined as part of the design process, significant reductions in rolling resistance can be achieved while at the same time extending maintenance intervals on the road and reducing overall road deterioration rates.

Modelling rolling resistance progression. The rolling resistance of a haul road is primarily related to the wearing course material used, its engineering properties, and the traffic speed and volume on the road. These dictate, to a large degree, the rate of increase in rolling resistance. Ideally, road rolling resistance should not increase rapidly — which implies that those road defects (roughness defects) leading to rolling resistance should also be minimized. This can be achieved through careful selection of the wearing course or sheeting material, which will minimize, but not totally eliminate, rolling resistance increases over time (or traffic volume).

To estimate rolling resistance (RR) at a point in time, an estimate of the roughness defect score (RDS) is required, and this can be determined from an initial estimate of the minimum and maximum roughness defect scores (RDSMIN, RDSMAX), together with the rate of increase (RDSI). Rolling resistance at a point in time (D days after road maintenance) is then estimated from a minimum value (RRMIN) and the associated rate of increase.

The equations given below are used, together with the parameters and variables defined in Table 1. When using these equations, care should be taken to ensure the parameters limits are comparable to the values used in the original research.

$$RDS = RDSMIN + \left[\frac{RDSMAX - RDSMIN}{1 + exp^{(RDSI)}}\right]$$

where:

$$RDSMIN = 31{,}1919 - 0.05354.SP - 0.0152.CBR$$
$$RDSMAX = 7.6415 + 0.4214.KT + 0.3133.GC + 0.4952.RDSMIN$$
$$RDSI = 1.768 + 0.001.D(2.69.KT - 72.75.PI - 2.59.CBR - 9.35.GC + 1.67.SP)$$

and

$$RR = RRMIN + RDS.exp^{(RRI)}$$

where:

$$RRMIN = exp^{(-1.8166+0.00028V)}$$
$$RRI = -6.068-0.00385.RDS+0.0061.V$$

Parametric relationships have been proposed by means of which the key variables described in

Table 1 can be approximated from the particle size distribution of the wearing course material. California Bearing Ratio (CBR) relationships have been proposed by Breytenbach et al.(2010), Yildirim and Gunaydin(2011) and Varghese et al.(2013), while Atterburg limits (PI) have been estimated by Schmitz et al.(2004) and Dolinar et al.(2007).

Photogrammetry and digital image processing

Photogrammetry refers to the process of taking measurements from photographs, and in this particular application, specifically, the conversion of digital images of a haul road wearing course material into its representative size fractions or PSD, often referred to as digital image analysis or the use of digital image analysis technology. Combining software and digital photography allows for the automation of photogrammetry. In the case of automated estimation of PSD, many measurements are required at a very high accuracy in order to accurately predict particle size distribution, especially in the case of smaller particle sizes.

The history and development of digital image analysis software for particle size distribution has been largely based around blast fragmentation and conveyor belt material sizing. It has also seen application in the assessment of gravel river beds for ecological studies (Bunte and Abt, 2011). Most recently, through Hahn's(2013) research on photogrammetry for particle size analysis, the accepted consensus is that digital image analysis is the current ideal technology to replace physical sieve analysis.

There are currently many commercial software options for PSD by digital image analysis. Such options include; Split-Desktop and Split-Online, Wipfrag, GoldSize, FragScan, TUCIPS, CIAS, Power Sieve, IPACs, KTH, WIEP, Fragalyst and Sedimetrics. Many other experimental software packages specific to mining have been created, and with minor adjustment, many other digital image analysis software can be applied to resolving particle size distribution (Anderson et al., 2012; Al-Thyabat et al., 2007).

To create a particle size distribution, the most common process utilized by photogrammetry software consists of the following generic steps, described by Pastor(2014):

1. Convert to grayscale.
2. Correct for radial lens distortion.
3. Correct for the camera axis not being perpendicular to the surface.
4. Identify individual grains.
5. Separate the 'touching' grains.
6. Measure the selected grains.
7. Square-hole sieve correction (in this case for Australian Standard AS 1289.3.6.1, 2009).

Given the size ranges of interest for a typical haul road sheeting material, (from course gravels (75 - 26.5 mm) through to fine sands (0.425 -

Table 1

Parameters and variables in rolling resistance progression models.

Parameter	Description
RDS	Roughness defect score.
RDSMIN	Minimum roughness defect score immediately following last maintenance cycle.
RDSMAX	Maximum roughness defect score.
RDSI	Rate of roughness defect score increase.
RR	Rolling resistance (N/kg).
RRMIN	Minimum rolling resistance at (RDS) = 0.
RRI	Rate of increase in rolling resistance from RRMIN.
Variable	**Description**
V	Vehicle speed (km/h).
D	Days since last road maintenance.
KT	Average daily tonnage hauled (kt).
PI	Plasticity index of wearing course.
CBR	California Bearing Ratio of wearing course material (at 100% Mod MDD and 4-day soaked).

Figure 5

PSD results of Split-desktop digital image processing.

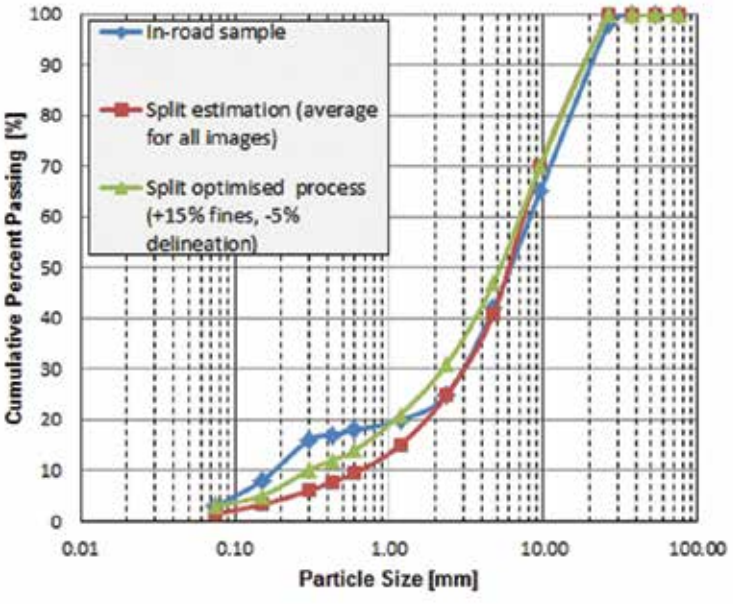
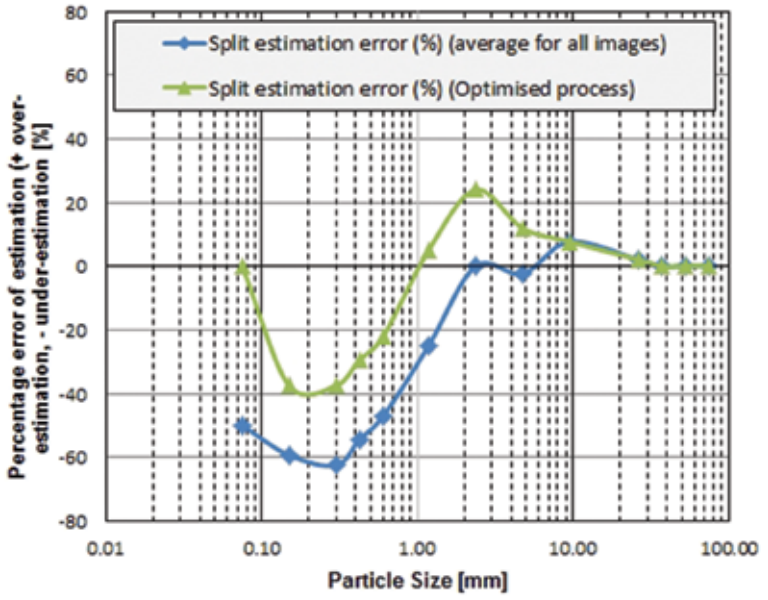


Figure 6

PSD estimation errors for default setting (all images) and manually optimized process.



0.075 mm), the most critical steps that affect the quality of a PSD produced by photogrammetry software are 4 and 5, i.e. 'identify individual grains' and 'separate the touching grains'. In step 4 — identifying individual grains — the process involves converting the original image to grayscale then converting into a binary (black and white) image. The key steps and procedural controls that define accuracy of a binary image consist of the following:

- Noise (graininess), in which fines measurement is maximized through minimizing 'noise.'
- Filter enhancement, in which the small dark regions between particles that were originally identified as only voids are enhanced. Therefore, in optimizing fines measurement, a small filter is utilized in order to identify more of the voids as fines particles.
- Thresholding to correct for intergrain noise, in which the filter enhanced image is converted into two binary images by thresholding at two differing intensities. With respect to identifying fines in haul road wearing course, a low intensity for threshold one and a high intensity for threshold two is used, whereby, the first threshold identifies all of the voids in the image (likely to include unwanted inter-grain noise) and the second threshold identifies only the darkest points in the image (that are much more likely to be only voids). Filter one will optimize fines measurement and combining this with filter two, will also represent accurate measurement of larger particles.

Figure 7

Typical raw image of mine haul road wearing course.

In step 5, the most common segmentation process is a watershed segmentation process, which relies on identifying the distance between a grain pixel and its nearest void (or edge of the grain). Thus, the algorithms utilized are inherently biased toward what has been identified as a grain from the binary segmentation process in step 4. Overall, the pixel density and clarity will dictate the accuracy of the watershed segmentation output. Research has illustrated that the watershed segmentation method is effective at identifying fines particles and is only bound by the number of clear pixels that contribute to form a grain. Thus, the watershed segmentation algorithm is dependent predominately on whether the original image has high enough pixel density to identify all fines particles (Pastor, 2014).

An empirical estimation of particle size identification limits and the relationship to the pixel density of its sample can be obtained from the equation presented below (after Sedimetrics(2006):

$$A = \left[\frac{g\sqrt{P}}{23000}\right]^2$$

where:
A = Area of photographic image (m^2)
g = b-axis of smallest grain of interest (mm)
P = Number of pixels in the image

The equation above would indicate that across the size ranges typically encountered in mine haul road wearing course materials,

multiple-sized images would be required to fully characterize the PSD. Taking the smallest image size (and thus highest pixel density) available from a mid-range digital camera (Canon EOS 60D D-SLR and Tamron optical zoom lens 18-270 mm), a minimum particle size of 0.3765 mm would be discernible at an image area of 0.0048 m^2 (representing minimum focal distance image area of 60 x 80 mm) with a maximum of 18 Megapixels at 5184 x 3456 pixel density. This image area (60 x 80 mm) is not suitable for recognition of the larger size ranges in the sample, and multiple images would be required, of increasing image areas, to estimate the full PSD.

Using this premise, two evaluations were undertaken to assess the suitability of commercially available digital image analysis technology to meet the needs of a real-time mine haul road wearing course material evaluation.

Digital image processing trials with haul road wearing course samples

Two trials were undertaken:

1. Split Engineering (Split-desktop) digital image analysis software.
2. Sedimetrics (Loughborough University) Digital Gravelometer.

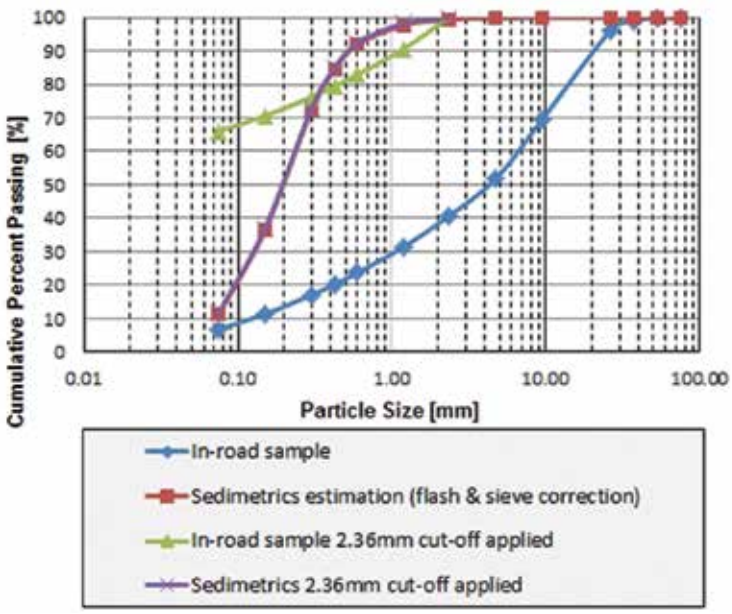
Both trials adopted samples of in-service mine haul road wearing course materials, which were photographed in-road and sampled. Sample PSDs were assessed following Australian Standard AS 1289.3.6.1, 2009 to determine the reference PSD in each case. In addition, although not reported here, several variations in the photographic technique were also assessed, including capture resolution, scale (pixels/mm), exposure time, F-stop and focal length and image illumination by Hahn(2013) and Pastor(2014).

Trial 1: Split-Desktop. Split-Desktop provides several adjustable settings for the automated assessment of PSD (automated delineation) from photographs. These factors are level of delineation, auto-fines (particles identified as fines) and fines factor (Split Engineering, 2014). For initial testing, default settings for automated delineation were used, with fines factor set to 50 percent, based on recommendation from the Split-Desktop manual.

Results from initial testing across all samples were similar, and Fig. 5 presents the comparative PSDs from the laboratory sample assessment and digital image processing. Figure 6 shows the percentage error by which percent passing varies across the respective sample assessment

Figure 8

PSD results of sedimetrics digital image processing.



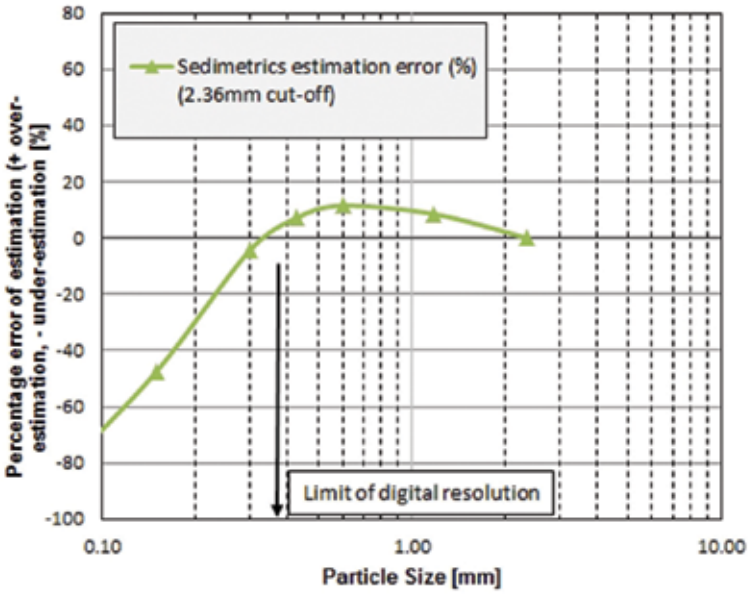
techniques with respect to sample particle size. A positive percent error indicates overestimation and conversely, negative percent error indicates underestimation.

A sensitivity analysis was undertaken to ascertain the role of the adjustable settings (delineation sensitivity and particles identified as fines sensitivity) with a view to reducing estimation errors. Figures 5 and 6 summarize the results from the optimum automated delineation settings. In general, the key issues identified were associated with coarse gravel particles (>26.5 mm) having a tendency to be broken up into smaller particles. Well-graded materials appear to have large border zones, causing a larger influence of the fines factor. Medium and fine gravels (4.75-26.5 mm) appeared to be influenced by fines obstruction substantially more than other sized particles.

Practically, it was noted that fines tend to stick to larger particles, likely influenced by the roughness height and the natural moisture content of the material. This meant that material was predominantly resolved as fines, not larger material. The primary issue however was resolution of material below 1.18 mm in size. Results from experimentation indicated that 1.18 mm was the limit for accurately identifying particles through delineation of boundaries, using this approach with a 5,184 by 3,456 capture resolution and pixel density of 8.87/mm (approximately 390 x 580 mm image). It was evident that a much higher pixel density was required for improved determination of fines, albeit at the expense of coarse gravel fraction determination.

Figure 9

PSD estimation errors for Sedimetrics with 2.36 mm cutoff applied.



Trial 2: Sedimetrics Digital Gravelometer. Options within Split-Desktop for increasing the resolution of very small image areas of the blasted material are not relevant to its primary application – blast fragmentation. Sedimetrics, however, is not bound by blast modeling parameter constraints and the program could deliver higher fines accuracy, as the particle identification algorithms utilized have fundamentally no limit to the level of fines accuracy obtainable (Graham et al., 2006).

For digital image collection, Pastor (2014) determined that the use of a flash enhancement delivered better quality images for processing, and when coupled with a sieve correction (0.79 -related to an average flatness of 0.51 as determined by Graham et al., 2006), delivered more representative results, in which fines identification was increased, but not over-estimated.

Figure 7 shows a typical raw image adopted for processing, representing an area of approx. 25 mm x 50 mm. Figure 8 represents the mean averages of the in-road sheeting sample laboratory PSD results in comparison to the processed digital images (with flash and sieve correction applied). It is evident that the photographic results are skewed to approximately 99 percent passing 9.5 mm. This is attributed to the limited image area, the implication being that no particles can be measured that are larger than 25 mm and at such a size, the image would poorly represent actual material sizing.

To investigate the fines accuracy of the software in comparison to the sample PSD; a cutoff was applied at the coarse sand size of 2.36 mm particle size. Figure 8 represents the redefined PSD at 2.36 mm cutoff. The PSD of the finer fractions closely matches the physical results between the lower limit of resolution (0.3 mm) and 2.36 mm. As anticipated by the minimum resolvable grain size estimation equation, particle sizes in the range of 0.075 - 0.3 mm were underestimated by digital processing. The associated percentage errors are shown in Fig. 9. The error in the particle sizes ranges 0.25 - 2.36 mm are all below 15 percent.

The level of variance within the percentage error between the ranges of 0.425 mm – 2.36 mm was also tested at 90 percent confidence intervals. Within 0.425 mm – 2.36 mm, the in-road images all varied by a maximum of 4.3 percent to their respective mean average (i.e. from 36 percent to 45 percent passing at 2.36 mm). This implies that there is high confidence that the processed digital images will be consistently accurate to within 15 percent of the physical data across this size range.

Conclusions and recommendations

The outcome from this work confirms that industry standard photogrammetry software has potential in meeting the required minimum particle size resolution of 0.425 m for the analysis of a mine haul road surfacing material, to determine real-time deterioration, based on PSD assessments. The analytical process required to meet the defined level of fines measurement was feasible and equipment and processes were cheap, fast, consistent and reproducible. With rigorous parametric relationships to CBR and Atterburg limits, the technique could be further extended to modeling changes in rolling resistance due to the interactive effects of surfacing material breakdown and traffic volumes and vehicle speed.

However, further work needs to be done to fully meet the grading coefficient estimation requirements in which medium to coarse gravel particle sizes between 2.36 - 75 mm are assessed contemporaneously with the fines fractions, to produce a complete PSD. This approach could be based on either a higher resolution camera/sensor to enable a larger image area to be captured, or tiling multiple images into a composite 75 x 150 mm image, using nine tiles of 50 x 25 mm high pixel-density images. This will allow fines accuracy to be obtained in the smaller image tiles, while also enabling larger particles within the same control area to be measured by utilizing tiled composite images. ■

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Remote operating station for dozers introduced

The new Remote Operator Station for Dozing, part of Cat MineStar Command for dozing, provides a safe, comfortable environment removed from the active dozing area. The station itself is modeled on the actual cab of the machine, with all ergonomic controls, alarms and features operating just as they do in the dozer. The system can be equipped for line-of-sight operation or for tele-remote operation with the addition of video feeds from the site and optional video and audio feeds from the dozer.

The Remote Operator Station is available for the D10T, D10T2, D11T and D11T CD. The remote station controls are fully integrated with these Cat dozers and provide quick response and enable use of onboard dozer systems, such as Auto-Carry, Auto Blade Assist and Automatic Ripper Control. The Remote Operator Station also integrates with Cat MineStar Terrain capabilities, such as grade control and avoidance zones. The system also allows switching control quickly and easily from one dozer to another, which enables one operator to control multiple dozers when the work does not require simultaneous operation.

The design of the Remote Operator Station allows it to be configured for easy transport in a truck or trailer, which adds flexibility in its application. Remote operation allows dozers to be used under highwalls and in other situations that present potential safety and health hazards. Typical applications include highwall and edge work, operation on or near unstable ground, leach pad ripping and maintenance, aggressive ripping, and pushing stockpile material to underground feeders.

A dozer operates from a remote operating station.

Building further on these technologies, Caterpillar is working with select mining customers to develop and field test the Cat semi-autonomous dozing system, which enables one operator to manage multiple dozers simultaneously. ■

What a ride;
From the mining industry to university

by S.D. Rosenthal

This article will share my 'shift in career direction' journey from corporate mine engineer, with 31 years of mining various commodities with a wide range of responsibilities in a variety of countries, to the world of academia. There are times in one's career that a change is required, albeit perhaps not as drastic of a change as moving to teaching. This paper will share how the transition arose, the decision to make the change, the challenges of the first year in academia and the journey within academia going into the second year.

As a graduate of the Montana College of Mineral Science and Technology (Montana Tech) with a B.S. mining engineering degree in May of 1982, my first job with Utah International in the Farmington, NM area took me back to my home state of New Mexico. Some of you will remember that the early 1980s was not a period of prolific opportunities for mining engineers, given low commodity prices, especially for copper (for example, Anaconda Co. had been taken over by Arco and was in the midst of closing down its Butte operations). Coal was good and the learning opportunities abounded with Utah (which became BHP and then BHP Billiton).

Gold was taking off in the mid to late 1980s thanks to use of cyanide and heap leaching technology improvements, coupled with deregulation of the gold price, so I ventured off to work in the gold industry with a (then) junior Canadian company called Barrick at a new acquisition of theirs known as Goldstrike. That same gold surge was causing a shortage of iron ore mining engineers in Australia. So after a few years in Nevada, I uprooted the family and left for a little town in the Pilbara of West Australia, known as Newman, to work in the iron ore industry with BHP Iron Ore. An initial short overseas posting turned into six plus years before transferring to BHP's Indonesian steam coal mines in Kalimantan on the island of Borneo. BHP was going through a rough period following some ill-fated projects (Magma Copper purchase, Beanup and HBI) and was reviewing assets and staffing, so internal opportunities became scarce. Employees were encouraged to "leave the company and find work elsewhere." So, off I went to Argentina to try copper mining in the Andes with Minera Alumbrera. This short stint in South America was followed by a move to another mining town, Morenci, AZ, and a posting with Phelps Dodge (now Freeport-McMoRan). After 12-plus years without living close to snow, we moved to the Denver, CO area in a new position with Newmont Mining Corp. Along the way I became a professional engineer (Nevada) and completed a masters in project engineering and management. After 11 years with Newmont, I moved to Butte, MT where I accepted a position as assistant professor of mining engineering.

My 31-year career has always been centered on surface mining activities in a variety of commodities (coal, gold, iron ore and copper) while living in diverse localities (Australia, Indonesia and Argentina as well as the United States). During my career in mining, I have worked both on the technical side (mine engineering, planning, design, scheduling and costing) as well as on the operations side (foreman, superintendent, mine manager). Corporate experience furthered my technical knowledge while adding a solid understanding of business, projects and strategic planning. I have led small to large teams, provided leadership in safety, and recruited/developed teams (including graduate mine engineer development programs) with a proven ability to perform in a wide variety of cultural environments.

From my application letter to Montana Tech: "At this time in my career, I have a strong desire to give back to the mining industry to ensure the safe and prudent continued exploitation of our natural resources. I can be most efficient at the 'giving back' through working with students in the development as future mine engineers and stewards of our natural resources."

So, how did I come to this conclusion?

From industry to academia

The short version of why I made the change to academia is that it was on my bucket list to teach. But how did I know it was "time," especially at a time when I had a senior role within Newmont's corporate mine engineering group?

First, there was an opening at Montana Tech. This wasn't the first opening at Montana Tech, as the mining engineering department had been suffering from turnover recently due to retirements and people pursuing other opportunities. Having an opening at least meant that I could put my hat in the ring. Obviously, when you are gainfully employed in a steady

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position with a decade at the same company, it is not wise to let your current employer know what you are chasing, otherwise it might jeopardize current ongoing employment.

Second, I had delivered several guest lectures at Montana Tech and assisted in developing and delivering internal Newmont mine engineering training. The experience was that teaching is fun, and its not overly difficult to develop material.

Third, self-reflection led me to apply. Newmont had invested in personal coaches for many senior-level technical personnel, and I was fortunate to have been selected to benefit from a coach. A part of the coaching experience included having a 360 review conducted. The 360 review incorporates feedback from your direct reports, peers, supervisor and the one-up supervisor who all weigh in on your leadership and management style. Results of the 360 review were a mix of good and bad, depending on your point of view.

In addition to the personal coaching, I read a plethora of leadership and management books while sitting on airplanes traveling to Newmont's far-flung sites. One of the books I read (Drotter, 2011) illustrated where I was in the corporate hierarchy and where the path ahead lay. I still had that "What do I want to be when I grow up" question nagging me. My coach aided me in my career vision by challenging me to identify my personal motivation and what brings passion to my efforts. I know that mining brings me passion. However, I was at a quandary of where to direct that passion — spending additional time in a corporate environment, moving to a mine site or trying something totally different. I chose the latter, as I realized, through the personal coaching and the reading, the intrinsic motivation of really enjoying my work had waned. I realized that I really need to know that I can directly help move the needle (sense of achievement) and continue personal growth (Pink, 2009).

Fourth, and probably most importantly, I had the support of Sonya, my wife of 25+ years. Sonya had spent elementary school years in Butte, so she was familiar with the city and has many other ties to southwestern Montana. Sonya's support was key to applying for the role of assistant professor at Montana Tech.

Fifth, Montana Tech needed to fill the position for fall semester 2013 whereas the interview was in December 2012. Assuming I was selected for the position, the additional time before starting allowed me to get some personal matters better organized before departing Newmont.

After many years in the mining industry the author landed at Montana Tech.

After the application and interview processes were completed, I was offered the position of assistant professor of mining engineering at Montana Tech.

The first year

OK, I got the job, now what? Oh, and by the way, I was told I was also going to be department head. I had compiled a 90-day plan for what I thought I could achieve (Watkins, 2003) which, in hindsight, was a bit ambitious given the change in work requirements from "doing" to "teaching."

I arrived to an office devoid of a "how-to" manual. My first discussion with the mining faculty was about the distribution of classes we would each be responsible for teaching. Sometime about here is when panic set in: it was the realization that I had to come up with more than just one guest lecture. I needed something in the order of 120 lectures given the three courses I agreed to take on. How does one plot out three, 50-minute lectures per class per week over a 15-week period when you don't know if you will be ahead or behind the plan for each lecture?

Help from inside

Thanks to the existing faculty (especially Thomas Camm and Paul Conrad) for sharing their notes, syllabus and lecture slides for two of the courses I was taking on. Without these, I would have not made it a week in the new role. Having a base to start from allowed me to add content, to change examples, and to re-use existing material to fit my style and needs.

Help from afar

One course I was taking on was taught the previous year by an adjunct professor (Jeffrey Johnson) then on loan from NIOSH. He had sent over a comprehensive quantity of material for the class all housed on a thumb drive. I could now use R&D (rip-off and duplicate) to get this course set up for my style. In addition to the course notes sent over, Johnson gave me one of the best pieces of advice that reduced my anxiety level in class

planning, and it was something to the effect of "Be ready for the next class and the one after that, don't try to map out the whole semester." That little bit, easy to some, advice gave me the focus and hope that I could tackle this teaching gig.

Survival

Thanks to the excellent support of the other faculty, and the plethora of material available on the worldwide web, fall semester was hectic, but we survived. A campus resource available to aid one in this journey, a small group instructional diagnosis (SGID), was used to provide feedback on my teaching. When an SGID is conducted, an outside faculty member comes to your class and asks the students what is working, what isn't working and what recommendations they have for the professor. This feedback helped me to adjust my teaching quality as part of continuous improvement in delivery of content.

Spring semester became easier as the department hired the remaining open faculty position, thereby reducing course loads on all.

Year two

The second year began without the jitters of the first year. The focus now was on reviewing, refining and upgrading the course notes from the year before. Now, was left to tackle more of the other stuff academia works on: recruiting students, writing research proposals, completing performance reviews, re-invigorating the Industry Advisory Board, planning for the next ABET review, etc.

The journey continues

As Thomas Camm once told me, teaching is like having a mistress that says when you depart, "Today was OK, but what are you going to bring me tomorrow?"

In closing, I love the change from industry to academia. I am having more fun than one person should be paid to do. Job satisfaction comes from several areas. First, I work with some tremendous faculty who bring more than 100 years of work experience prior to full-time teaching. Our faculty has complementary skills in teaching and experiences with little overlap and five unique personalities.

Second, satisfaction is derived from working with the student, seeing the growth in their skills, being able to present real-world problems for them to solve, and seeing the passion in them for the industry, especially after their first internship.

Third, there is genuine support and an overwhelming positive response from industry for the department faculty and for me as the department head. The sense of achievement has returned for me, as I am able to award scholarships to help students pay for school and knowing that they might graduate debt free. Helping students find internships and full-time employment through connections and referrals is sometimes time consuming yet very rewarding at the end of the day. Support from colleagues in making the transition has been tremendous and has been followed up with guest lectures provided and supplying projects for senior design. Reconnecting with alumni and connecting with new alumn fosters additional support for the department and Montana Tech.

It isn't all beer and skittles. Stress is present, but it is not the kind of stress that keeps me up at night as in industry. Stress comes in the form of ensuring quality time is given to the students in the class room and I am available for consultation on their agenda. Hours can be long when devoting the time to the class, the students and the campus. Drivers for performance are different, members of academia don't have to make tons or grade or a safety target, but have to ensure we are teaching well, pursuing research and giving back to the community. And the annual performance review has no guarantee of a pay raise, as that is in the hands of the state legislature now. Oh yea, and forget about production/performance bonuses.

Lastly, yes, there is a pay difference from industry to academia. Academia pays well compared to the "average wage" for Montana and is exponentially different than industry. To embark on such a radical income change one has to be able to downsize, not take on additional debt, or be in a position that a second income makes up the difference. Compared to Denver, I can walk to the office thus reducing commute time and costs. The cost of living in Butte is reasonable, and access to the outdoors is at least an hour closer. Butte doesn't have as many distractions to spend your money on, like Broncos season tickets — you can still catch all of the games in the warmth of your living room, and beers don't cost seven dollars.

I have seen the graduates of 2013/2014 depart for new adventures with 100 percent placement for U.S. citizens. I do not know if in such a short time I had any influence on those first graduates, but I am sure I am impacting this year's. ■

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National Mining Hall of Fame names class of 2015 and Prazen award winner

The National Mining Hall of Fame and Museum (NMHF&M) announced the 2015 National Mining Hall of Fame inductees and the 2015 Prazen Award winner. This year's inductees, selected by the National Mining Hall of Fame's Board of Governors, represent the technology, management, mineral policy, education and health and safety aspects of the mining industry. They envelope a diverse cross section of the mining industry and were selected for being visionaries, leaders, educators and ambassadors.

In 2015, Frank F. Aplan, T S Ary, Ralph E. Bailey, John Campbell Greenway and Edward Steidle will join 227 other mining industry honorees when formally inducted into the National Mining Hall of Fame. The Prazen Living Legend of Mining Award will go to the Powell River Project Research and Education Center, a partnership of Virginia Polytechnic Institute and State University (Virginia Tech) and the Appalachian coal mining industry.

The 2015 annual induction banquet and ceremony will be the 28th such event and will be held this year in Pittsburgh, PA, on Oct. 23, 2015, in the Omni William Penn Hotel ballroom.

Frank F. Aplan

2015 National Mining Hall of Fame inductees:

Frank F. Aplan is among the most influential mineral processing leaders in both industry and academia. His studies of the processes involved in the preparation of coal and mineral ores are acknowledged worldwide for their broad applicability. An authority on flotation, Aplan is especially known for his studies of the wetting of solids and their control through the adsorption of surfactant films, and for his work on atomic defects on properties and behavior of solid-liquid interfaces.

T S Ary

Ralph E. Bailey

National Mining Hall of Fame

John Campbell Greenway

Edward Steidle

T S Ary was a leader in mineral exploration and a champion of economically and environmentally sustainable mineral policies. A prolific author and advocate for the mining industry, Ary was a recognized authority on mineral policy who served on the U.S. State Department Task Force to the United Nations Law of the Sea Convention and on the Mineral Advisory Committee to the Department of Commerce. In 1988, Ary was sworn in as the 18th Director of the U.S. Bureau of Mines.

Ralph E. Bailey is a distinguished veteran of the coal industry, regarded not only for his impressive accomplishments as a mining industry executive, but also for his staunch commitment to safety, engineering and improving mine operations. Bailey was also responsible for implementing many effective new concepts, including the first longwall system to operate in eastern bituminous coal and the implementation of a program to improve the health and safety of underground and surface miners.

John Campbell Greenway possessed unique engineering and managerial talents. He led development of the Western Mesabi Iron Ore Range in Minnesota and, along with L.D. Ricketts, developed and patented the technology for leaching copper ores and electrowinning the leached solutions. Praised for heroic conduct in WWI and awarded the Croix de Guerre and l'Etoile, Legion of Honor and Distinguished Service Cross, a statue of Brigadier General Greenway stood in the U.S. Capitol for 85 years.

Edward Steidle was an influential visionary leader of U.S. mineral education who recognized the need to bring under one roof all of the sciences and technologies needed to discover, extract, process, utilize and conserve mineral wealth for the benefit of humanity. Accordingly, Steidle created the College of Earth and Mineral Sciences while Dean at Penn State, where he taught and shared his ideas and philosophy on mineral education and conservation.

2015 Prazen Award Winner:

The Powell River Project Research and — Education Center — The 2015 Prazen Award will go to the Powell River Project Research and Education Center, a program of Virginia Tech that conducts research and education programs to enhance the restoration of coal-mined lands in partnership with the Appalachian coal mining industry.

The Powell River Project was created in 1980 in direct response to coal mine reclamation challenges presented by the Surface Mine Control and Reclamation Act of 1977. Its purpose has been to identify reclamation practices and post-mine land uses most beneficial to communities in the coal-field region, particularly in the realm of reclaiming and reforesting mined lands with native hardwood species, and the utilization of reclaimed areas for agriculture and horticulture. Each year, hundreds of people visit the Center to learn about mining, reclamation, and environmental protection at Appalachian coal mines. Since its establishment, more than 50,000 visitors have participated in educational programs at the Center.

Commenting on this year's inductees and Prazen Award winner NMHF&M Board of Directors Chairman Frank McAllister said, "We are pleased and honored to induct such an outstanding group of mining industry professionals. Among the inductees are professionals who made exceptional contributions to the mining industry in the United States, including two living inductees who made significant contributions to management and technology in the industry. We are also delighted that The Powell River Project Research and Education Center is to be recognized for its 35 years of outstanding stewardship to Appalachia."

Biographies and photographs of all past inductees can be accessed on the NMHF&M website at www.mininghallofame.org along with additional information about the museum and its facilities. ■

Editor's note: As a service to *Mining Engineering's* Spanish-speaking readers, this page contains brief summaries of the feature articles that are in this issue.

Nota del Editor: Como un servicio a los miembros de habla hispana de la revista Mining Engineering, esta página contiene resúmenes breves de los principales artículos y de los documentos técnicos revisados por pares que se encuentran en esta edición.

Desarrollo de monitoreo de la condición de la superficie de vías de acceso a minas a través del procesamiento de imágenes digitales

por S. Hahn, S. Pastor y R. Thompson

Conforme avanza el concepto de los Sistemas de Camión Autónomos (AHS por sus siglas en inglés) de prototipos a aplicaciones listas a ser producidas el rendimiento operativo de las vías de acceso serán esenciales para el éxito general de la autonomía en la minería. El deterioro en el rendimiento de la vía requerirá medidas correctivas, intervención humana y cambios significativos, aunque temporales, en los procedimientos operativos para el realizar el mantenimiento de las vías de acceso. Con los camiones autónomos viene la oportunidad de reducir la formación del camino y la superficie de la anchura de trabajo. Por tanto, esto generará potenciales y significativas reducciones en la proporción del desmonte y las mejoras en la economía de mina, pero esto solo será si el diseño del camino y su ratio de deterioro asociado es predecible y manejable en base a los materiales usados en su construcción y las intervenciones para mantenimiento a ser realizadas en la vía. ■

Que cambio; De la industria minera a la universidad

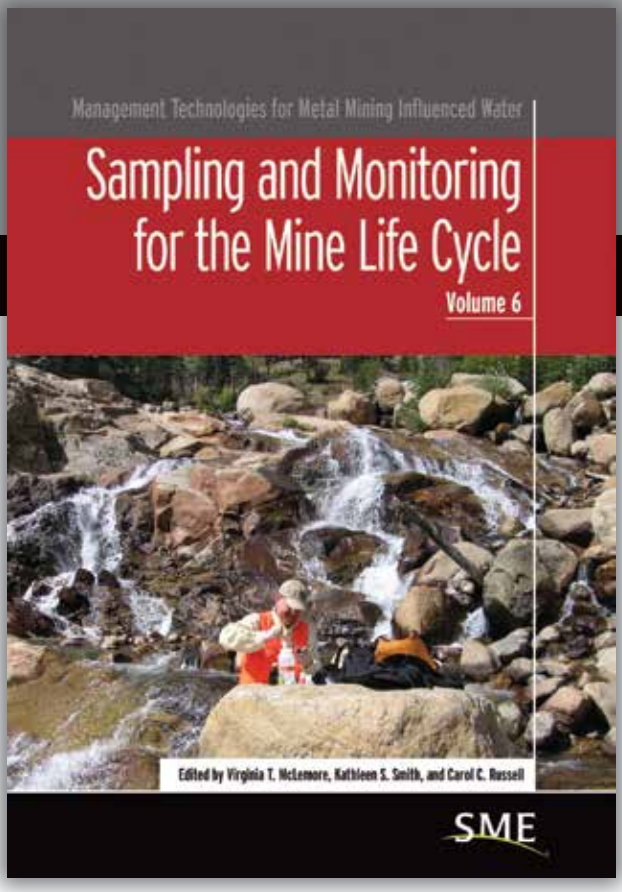
por S.D. Rosenthal

En este artículo compartiré el cambio de dirección de mi carrera de ingeniero de minas corporativo, con 31 años en la minería de varios commodities, con una amplia gama de responsabilidades en diferentes países, al mundo académico. Existen momentos en la vida laboral de una persona en la que se requiere un cambio, aunque tal vez no uno tan dramático como dedicarse a la enseñanza. Este artículo les contará como surgió esa transición, la decisión a efectuar ese cambio, los desafíos del primer año en el mundo académico y el camino hacia el segundo año. ■

El Salón Nacional de la Fama de la Minería nombra a la promoción 2015 y al ganador del premio Prazen

por S.D. Rosenthal

El Salón Nacional de la Fama de la Minería y Museo (NMHF&M por sus siglas en inglés) anunció a los nuevos inducidos al Salón Nacional de la Fama de la Minería 2015 y al ganador del premio Prazen 2015. Los seleccionados para este año por la Junta de Gobernadores del Salón Nacional de la Fama de la Minería, representan aspectos de la tecnología, gestión, políticas de mineral, educación y salud y seguridad de la industria minera. Ellos conforman una muestra representativa diversa de la industria minera y fueron seleccionados por ser visionarios, líderes, educadores y embajadores. ■



Sampling and Monitoring for the Mine Life Cycle

Edited by Virginia T. McLemore, Kathleen S. Smith, and Carol C. Russell

Sampling and Monitoring for the Mine Life Cycle provides an overview of sampling for environmental purposes and monitoring of environmentally relevant variables at mining sites. It focuses on environmental sampling and monitoring of surface water, and also considers groundwater, process water streams, rock, soil, and other media including air and biological organisms. The handbook includes an appendix of technical summaries written by subject-matter experts that describe field measurements, collection methods, and analytical techniques and procedures relevant to environmental sampling and monitoring.

The sixth of a series of handbooks on technologies for management of metal mine and metallurgical process drainage, this handbook supplements and enhances current literature and provides an awareness of the critical components and complexities involved in environmental sampling and monitoring at the mine site. It differs from most information sources by providing an approach to address all types of mining influenced water and other sampling media throughout the mine life cycle.

Sampling and Monitoring for the Mine Life Cycle is organized into a main text and six appendices that are an integral part of the handbook. Sidebars and illustrations are included to provide additional detail about important concepts, to present examples and brief case studies, and to suggest resources for further information. Extensive references are included.

Contents

- Introduction
- Sampling and Monitoring During the Mining Phases
- Sampling Considerations in the Mining Environment
- Decision Making, Risk, and Uncertainty
- The Planning Process
- Sampling and Monitoring Program Implementation
- Data Management, Assessment, and Analysis for Decision Making
- Additional Key Issues and Future Research Needs
- Selected Online Resources
- Summary of Selected ASTM Methods
- Summary of Field Sampling and Analytical Methods
- Examples of Sampling Plans and Quality Assurance Project Plans
- Case Studies of Sampling and Monitoring
- Applications and Examples of Geo-Environmental Models

Sampling and Monitoring for the Mine Life Cycle

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Engineering practices for a safe, inert atmosphere in sealed areas of coal mines

by R.K. Zipf, Jr.

Abstract ■ The 2008 Mine Safety and Health Administration Final Rule on Sealing of Abandoned Areas of Coal Mines focuses on seal design to resist explosion pressure. By designing sealed areas to become inert and remain permanently inert, it may be possible to use more economical 345-kPa (50-psi) seals under the new rule, if the required monitoring is met. Most sealed areas pass through the explosive range for methane in air within a few weeks after seal construction and then remain inert permanently, but data about the proportion of sealed-area atmospheres that are permanently inert and safe are lacking.

Certain practices that were in use prior to the new regulation may have contributed to the formation of explosive atmospheres within sealed areas. Sealing low-methane-inflow mines at shallow depth may have created explosive atmospheres in sealed areas that persisted for months or more. Complex seal lines involving many seals could have led to some parts of the seal line ingassing to form an explosive mixture and other parts of the line outgassing to increase the methane gas load on the ventilation system.

Recommended engineering practices to create and maintain permanently inert atmospheres within sealed areas are: (1) better overall mine layouts, (2) better mining practices near future seals and (3) better ventilation system design. Planning the mine layout is required years in advance of sealing to minimize the number of seals required and to simplify the ventilation system considerations. Several practices to consider following near a future seal construction site are to (1) minimize the number of entries into panels, (2) increase the cross-cut spacing, (3) decrease the entry width and (4) increase ground support. When designing the ventilation system, minimize the pressure differential across seals and increase the resistance across seals and seal lines to decrease air exchange with sealed areas.

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Introduction

Coal mine seals are permanent structures constructed in underground coal mines to separate unventilated abandoned mine workings from ventilated active mine workings. In 2006, explosions within sealed areas at the Sago and Darby mines resulted in mine disasters that claimed the lives of 17 miners. The explosion pressure in both cases was sufficient to destroy the 140-kPa (20-psi) seals, and the victims were either killed directly by the explosion forces or were asphyxiated by carbon monoxide from the explosion. These mine disasters caused mine safety researchers and regulators to reconsider the coal mine sealing process and the adequacy of the 140-kPa (20-psi) standard for coal mine seals.

This paper reviews seals and sealing practices before enactment of the 2008 seal regulation and discusses how certain sealed areas can contain an explosive atmosphere. The case is presented that most sealed areas likely contain an inert nonexplosive atmosphere, but scientific information on the atmospheres in sealed areas is lacking. This paper also discusses sealing practices in use prior to the new coal mine seal regulations that may have contributed to the formation of potentially explosive mixtures within sealed areas. Finally, engineering techniques are presented that can simplify sealing and promote the development of safe, permanently inert atmospheres within sealed areas.

Resumen ■ La Decisión Final en 2008 de la Administración de Salud y Seguridad en Minas sobre el Sellado de Áreas Abandonadas de Minas de Carbón se centra en el diseño del sellado que resista la presión de una explosión. De acuerdo con esta nueva decisión y mediante el diseño de convertir áreas selladas en inertes y que permanezcan inertes de manera permanente, sería posible el uso de sellos 345-kPa (50-psi) más económicos si se cumple con el monitoreo necesario. La mayoría de las áreas selladas pasan por el rango explosivo para metano en el aire pocas semanas después de la construcción del sellado y luego permanecen inertes permanentemente, pero se carece de datos sobre la proporción de atmosferas en áreas selladas inertes de manera permanente y segura.

Es posible que ciertas prácticas que estaban en uso antes de la entrada de la nueva regulación pudieran haber contribuido a la formación de atmósferas explosivas en el interior de áreas selladas. Sellar minas con bajo flujo de metano a poca profundidad puede haber creado atmósferas explosivas en áreas selladas con persistencia de meses o más. Líneas complejas de sellado que involucran muchos sellos podrían haber generado que algunas partes de la línea de sellado hayan sufrido ingreso de gases formando una mezcla explosiva y otras partes de la línea hayan tenido fuga de gases incrementando la carga de gas metano en el sistema de ventilación.

Las prácticas de ingeniería recomendadas para la creación y mantenimiento permanente de atmosferas inertes al interior de áreas selladas son: (1) mejor distribución general de la mina, (2) mejores prácticas de minería cerca de sellos futuros; y (3) un mejor diseño del sistema de ventilación. La planificación de la distribución de la mina debe ser realizada con años de anticipación con el fin de minimizar el número de sellos necesarios y para simplificar las consideraciones del sistema de ventilación. Varias prácticas a tener en cuenta para poner en práctica cerca al lugar de construcción de un sello futuro son: (1) minimizar el número d entradas a paneles, (2) incrementar el espaciamiento de corte transversal, (3) disminuir el ancho de entrada, e (4) incrementar el apoyo de tierra. Al diseñar el sistema de ventilación, minimizar el diferencial de presión a través de los sellos y aumentar la Resistencia a través de los sellos y aumentar la resistencia a través de los sellos y las líneas de sellos para disminuir el intercambio de aire con áreas selladas.

Background

From 1986 through 2006, 12 known explosions occurred within the sealed areas of active U.S. underground coal mines (Zipf et al., 2007). Nine occurred prior to the Sago Mine disaster. Table 1 summarizes their characteristics, such as the sealed-area size, damage, cause and suspected ignition source, based on the author's interpretation of the U.S. Mine Safety and Health Administration (MSHA) accident investigation reports and other information. Significant accumulations of explosive methane-air mixtures developed behind the seals that ultimately led to each explosion. Investigators could not always conclusively determine the ignition source and location. Lightning was suspected in several instances. Explosion pressures could not be determined reliably for many of the sealed-area explosions and were instead inferred from observed damage. Actual measurements of the pressures do not exist. Back-calculations from observed damage in one explosion reported in Table 1 indicated an explosion pressure of about 6.9 MPa (1,000 psi).

Since 2006, one additional explosion occurred behind seals at the Mount Pleasant Mine in July 2012. Apparently, the explosion did not damage the 800-kPa (120-psi) seals, but it did destroy the PVC drainage pipes emanating from the base of one seal in the set. No official reports are available for this incident.

The explosions in sealed areas that occurred in the 1990s and 2000s may correlate with the use of more seals in the U.S. underground coal mining industry. Unfortunately, quantitative data about the number of seals constructed annually do not exist. Mitchell (1971) noted that prior to World War II the sealing of unused and abandoned areas of coal mines was common practice. He also noted that the few seals built from 1945 to 1970 were mainly in mines with high risk for developing spontaneous combustion, implying a decline in the use of seals in that time period. The Federal Coal Mine Health and Safety Act of 1969 required mines to either ventilate all areas or seal them with "explosion-proof bulkheads." The act may have contributed to an increase of seal usage since 1969. Increased underground coal production may have also contributed to an increase in sealing and the number of seals used.

Prior to 2006, coal mine seals were built to withstand explosion pressure of 140 kPa (20 psi) (Weiss et al., 2002). However, for methane-air mixtures of sufficient size and volume, the worst-case explosion pressure can be much higher. The constant volume explosion pressure for methane-air is about 0.8 MPa (120 psi), and if detonation develops, the explosion pressure is about 1.66 MPa (241 psi) (Zipf et al., 2007). The 2008 MSHA Final Rule on Sealing of Abandoned Areas of Coal Mines specify new strength requirements for coal mine seals as 345 kPa (50 psi) if the sealed-area atmosphere is monitored and maintained inert or 800 kPa (120 psi) if the sealed-area atmosphere is not monitored and maintained inert (Federal Register, 2008). Most underground coal mines have opted to use stronger coal mine seals without monitoring rather than lighter seals with atmospheric monitoring of the sealed area.

Evolution of potentially explosive methane-air mixtures in sealed-area atmospheres

Before seal construction, the atmosphere in a ventilated area is nominal air with about 21 percent oxygen, 78 percent nitrogen and less than 1 percent argon, carbon dioxide and other gases. After seal construction, ventilating air in the

sealed area ceases to flow and the composition of the sealed-area atmosphere will begin to change. With few exceptions, methane gas emanates from the coal seam and surrounding rock strata, and the methane concentration in the sealed-area atmosphere will increase. Coal remaining in the sealed area can oxidize at varying rates and thereby remove oxygen and release carbon dioxide into the sealed-area atmosphere. Depending on gas release rates, sufficient methane may accumulate within the sealed area while sufficient oxygen is still present to form an explosive mixture of methane in air.

Methane in air is explosive over a concentration range of about 5 to 15 percent by volume, and potentially explosive mixtures of methane and air can form whenever the oxygen concentration is greater than about 12 percent by volume (Coward and Jones, 1952). Recent studies have extended the explosive concentration range for methane in air to 5 to 16 percent by volume (Cashdollar et al., 2000). The presence of combustible "fire gases" such as hydrogen and carbon monoxide with methane can widen this explosibility range considerably, and conversely, the presence of inert gases, particularly carbon dioxide, can decrease the explosibility range (Hughes and Raybould, 1960). During a mine fire, assessing the explosibility of the sealed-area atmosphere requires more complex models such as the Hughes and Raybould approach or an Ellicott diagram (Ellicott, 1981). However, this paper considers only routine coal mine sealing when an active fire is not present in the sealed area, and in this case the Coward and Jones model for explosibility of methane in air only is sufficient.

The critical time for a sealed area occurs while its atmospheric composition crosses through the explosive range when the methane concentration is 5 to 16 percent by volume and the oxygen concentration is greater than 12 percent by volume. Most sealed areas in U.S. coal mines will eventually enter this explosive range at some point in time after sealing. The critical time during which the sealed-area atmosphere might remain in this explosive range varies, depending on the methane inflow rate into the sealed area and the oxidation rate of the coal. In a few mines with high methane inflow rate, the critical time may be one or two days until the methane concentration exceeds 16 percent. In most mines with typical methane inflow rate, the critical time may be a few days to one week. However, in a few mines, the critical time within this explosive range can be several weeks to many months, or the sealed-area atmosphere may never leave the explosive range.

Likely behavior of most sealed-area atmospheres

The composition of sealed-area atmospheres in U.S. coal mines has not been studied extensively or systematically. Anecdotal evidence suggests that the composition of most sealed-area atmospheres likely becomes fuel-rich inert and remains inert within a week or two after sealing. There are few scientific reports that examine the self-inertization process and document the factors controlling it.

The self-inertization process of a sealed-area atmosphere usually involves some combination of methane inflow from the coal seam and surrounding strata and oxygen depletion through slow oxidation of carbonaceous material in the sealed area. For classification purposes, four categories arise from these two variables as shown in Fig. 1. In U.S. coal mines, it appears likely that the majority of longwall and large room-and-pillar mines can be categorized as high methane inflow rate and low oxidation rate (green portion in Fig. 1). Sealed areas in these mines likely emit sufficient methane to make the atmosphere inert within a week or two after seal construction, and the coal does not oxidize at a sufficient rate to decrease the oxygen concentration significantly in this time frame. As evidence for the low coal oxidation rate, most coal seams in the U.S., primarily in the eastern states, are not prone to spontaneous combustion.

In contrast, there are a few mines in the U.S. operating in coal seams that emit methane at a low rate and do not oxidize at a significant rate (red portion in Fig. 1). Sealed areas in these mines would gradually enter the 5 to 16 percent explosive range for methane-oxygen mixtures, and could remain there for weeks to months. Fortunately, the number of mines that fall into this category is likely small, but scientific data to confirm this supposition are lacking.

There are a few underground coal mines in the U.S. that have little or no methane inflow and high oxidation rates (yellow portion in Fig. 1). In addition, there may be a few mines with high methane inflow rate and high oxidation rates (blue portion in Fig. 1). Sealed-area atmospheres in these mines

Figure 1

Approximate portion of sealed-area atmospheres that may become inert within a week of seal construction (green), and approximate portion that may contain an explosive methane-air mixture for a longer time (red).

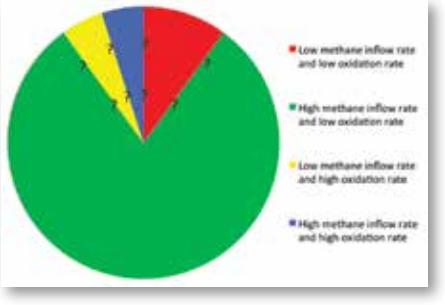


Figure 2

Approximate portion of sealed-area atmospheres in deep mines that may have an inert atmosphere (green), and approximate portion of sealed-area atmospheres in shallow mines that may have an explosive methane-air mixture (red).

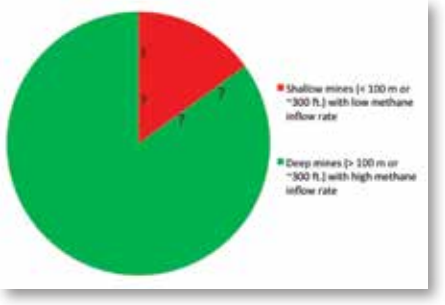


Table 1

List of 12 known explosions that occurred in 1986-2006 in the sealed areas of active U.S. underground coal mines.

Mine	Year (month)	Size of sealed area	Damage from explosion	Cause of explosive mix	Suspected ignition source	Estimated explosion pressure
Roadfork No. 1	1986	Several room-and-pillar panels	4 seals destroyed	Recently sealed area	Spark from rock fall	Unknown
Mary Lee No. 1	1993	Several square miles	2 seals destroyed and shaft cap displaced	Leaking seals	Lightning	14 kPa (2 psig)
Oak Grove No. 1	1994	Several square miles	3 seals destroyed	Leaking seals	Unknown	Unknown
Gary 50	1995	Several square miles	None; seals survived	Leaking seals	Lightning or roof fall	35–48 kPa (5–7 psig)
Oak Grove No. 1	1996	Several square miles	5 seals destroyed	Leaking seals	Lightning	< 35 kPa (< 5 psig)
Oasis	1996 (May)	Several square miles	3 seals destroyed	Leaking seals	Lightning or roof fall	< 138 kPa (< 20 psig)
Oasis	1996 (June)	Several square miles	Unknown	Leaking seals	Lightning or roof fall	Unknown
Oak Grove No. 1	1997	Several square miles	3 seals destroyed	Leaking seals	Lightning	> 138 kPa (> 20 psig)
Big Ridge Mine Portal No. 2	2002	Unknown	1 seal destroyed	Recently sealed area	Unknown	Unknown
Sago	2006	1 room-and-pillar panel	10 seals destroyed	Recently sealed area	Lightning	> 642 kPa (> 93 psig)
Darby	2006	1 room-and-pillar panel	3 seals destroyed	Recently sealed area	Oxygen/ acetylene torch	> 152 kPa (> 22 psig)
Jones Fork E–3	2006	Unknown	3 seals destroyed	Unknown	Unknown	Unknown
Mt. Pleasant Mine	2012 (June)	Unknown	Seals survived. PVC pipes for drainage destroyed	Unknown	Unknown	Unknown
Blacksville No. 1	1992	Shaft area	Shaft cap and collar destroyed	Recently sealed area	Welding sparks	6.9 MPa (1,000 psig)

also become self-inert quickly within days or a few weeks. As mentioned earlier though, there is little public scientific data to delineate the approximate proportion of mines or coal seams within the four categories shown in Fig. 1.

Another way to classify sealed areas of coal mines is by depth. The methane content for coal and the methane inflow rate are known to vary with depth and coal rank (Kissel, 2006). Sealed areas less than about 100 m (~300 ft) deep are often associated with low methane inflow rate, and they may be more likely to contain an explosive methane-air mixture compared with sealed areas greater than about 100 m (~300 ft) deep. Anecdotal evidence suggests that inert atmospheres may develop more readily within sealed areas of deeper mines with high methane inflow rate, and that explosive atmospheres may be more closely associated with sealed areas in shallower mines with low methane inflow rate. As indicated in Fig. 2, the number of deep, sealed areas that are inert likely exceeds the number of shallow, sealed areas that are more likely to contain an explosive mixture. Again though, there is little or no scientific data to ascertain the proportion of sealed areas that have become inert permanently, the proportion that may contain an explosive mixture for some period of time, and the proportion that might go in and out of the explosive range repeatedly. The proportions of sealed areas with inert or potentially explosive atmospheres shown in Figs. 1 and 2 are an approximation based on anecdotal evidence. The intent of the above discussions is to encourage scientific efforts to obtain the requisite data about sealed-area atmospheres and to show how to interpret and use that data for guiding sealing practices.

Another critical question concerns the volume or lateral extent of a potentially explosive atmosphere within a sealed

area. While the anecdotal evidence suggests that most sealed-area atmospheres become inert, some may contain an explosive mixture of unknown size for an unknown period of time.

Problematic sealed areas and sealing practices

Several factors concerning the sealed area itself or sealing practices in use at the time may have contributed to the explosions listed in Table 1. Eight of the 13 explosions may have occurred in "low methane inflow rate and low oxidation rate" mines (Fig. 1) or in "shallow mines with low methane inflow rate" (Fig. 2). An explosive mixture may have existed within these sealed areas for a long time, increasing the exposure time for an ignition to occur. However, information about the atmospheric compositions in the sealed areas of these mines, or their methane-inflow and oxygen-depletion rates is not available from the explosion investigations or any other published reports.

Several of the explosions may have resulted from leaking seals. Investigations showed that certain explosions only affected an area immediately behind the seals, suggesting that the seals and the strata surrounding the seals were allowing air to leak into the sealed area and create a localized explosive mixture. Prior to the Final Rule, the old seals were thinner than those in use today and certainly enabled more air leakage around the seals into sealed areas and the formation of potentially explosive mixtures.

Complex seal lines coupled with a large number of seals may have contributed to the development of explosive mixtures behind seals. Figures 3 and 4 show examples of mine layouts with complex seal lines that may have a tendency to leak and form potentially explosive mixtures. Both examples resulted in sealed-area explosions that are listed in Table 1.

Several problems can result from these extensive and complex seal lines. First and foremost, the sealed area itself might become an unintended branch of the ventilation system. Depending on the layout of the ventilation system, fresh air could leak through one set of seals (ingassing seals), and sealed-area gases could leak out through another set of seals (outgassing seals). In this situation, a potentially explosive mixture might accumulate in the sealed area near the ingassing seals. Ground control is another problem that can affect extensive and complex seal lines. Depending on the mine layout, the pillars and surrounding rock in certain areas may deteriorate and cause excessive rock pressure on seals, leading to deterioration and increased leakage through the seals and surrounding strata. The other issue is simply the number of seals. With more seals, there is higher likelihood of faulty construction or some other issue that leads to seal deterioration and leakage.

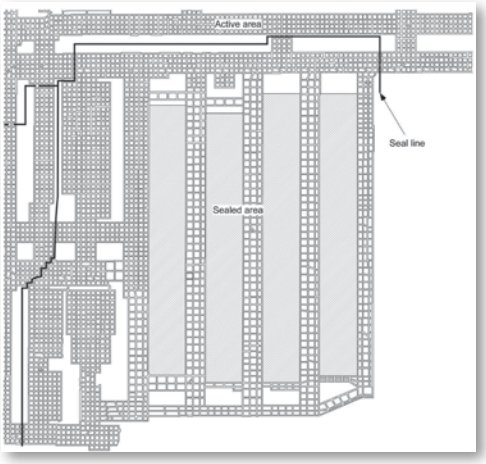
Suggested engineering practices for sealed areas

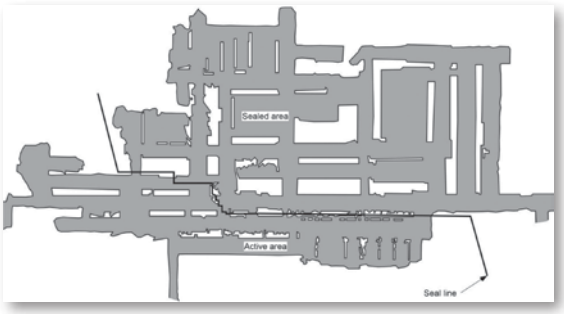
The new 2008 regulations for sealing of abandoned areas of coal mines require seals to resist a design pressure-time curve with maximum pressure of 800 kPa (120 psi) and instantaneous rise time if the sealed area is not monitored and could therefore contain an explosive methane-air mixture. For sealed areas that are monitored and maintained as inert, seals must resist a design pressure-time curve with maximum pressure of 345 kPa (50 psi) and instantaneous rise time. Instead of designing seal structures to contain the pressure from a potential explosion, an alternative approach is to design sealed areas that become inert quickly and remain permanently inert, which may enable the use of less expensive 345-kPa (50-psi) seals, provided the periodic monitoring requirements are met. The engineering techniques presented to promote an inert atmosphere in sealed areas include: (1) overall mine layout, (2) mining practices near future seals and (3) ventilation system practices.

Prior to sealing any area, planning engineers should measure the methane inflow rate and oxygen depletion rate within the future sealed area. Measuring these rates requires measurements of the air quantity and of the methane and oxygen concentrations in the ventilating air entering and exiting the future sealed area. Determining the methane and oxygen concentrations may require analysis with a gas chromatograph as opposed to a handheld device to measure these gas concentrations with sufficient accuracy and precision. From the approximate volume of the future sealed area, coupled with the methane inflow and oxygen depletion rates, the time required for the sealed area to cross through the explosive concentration range for methane in

Figures 3 and 4

Examples of a longwall mine (Fig. 3 – top) and a room-and-pillar mine (Fig. 4 – bottom) with complex seal line and many seals that are prone to simultaneous ingassing and outgassing and formation of potentially explosive methane-air mixtures. (The gray areas in Fig. 4 are room-and-pillar panels, generally seven or more entries wide.) Ingassing can occur in one area along the seal line while outgassing occurs elsewhere, depending on the layout of the ventilation system.





air can be estimated. This time required to achieve a safe, inert atmosphere can also be inferred from the behavior of nearby, sealed areas with similar conditions.

With adequate planning of the overall mine layout years in advance of actual seal construction, the number of seals needed to isolate the mined-out area from the active mining area can be minimized. Figure 5 shows a group of mined-out longwall panels, gateroads, submains and bleeder entries that can be sealed with relatively few seals, while Fig. 6 shows another longwall mining operation where relatively few seals are needed to seal and abandon the mined-out area. Note how the simple seal lines shown in Figs. 5 and 6 contrast with the extensive and complex seal lines shown in Figs. 3 and 4. Planning the seal locations years in advance could have a positive economic impact on operations since the number of seals required is minimized.

The sealed area shown in Fig. 5 is not subject to significant pressure differential due to the ventilation system. It is unlikely that some seals will leak air into the sealed area (ingassing) while others leak air out (outgassing), since the seal line is relatively short. This sealed area would tend to become inert and remain inert, except near the seals when barometric pressure changes could induce air leakage into the sealed area and formation of a potentially explosive methane-air mixture in that vicinity. A ventilation pressure differential could exist between the seal sets shown in Fig. 6. However, the pressure differential across the sealed area is limited to the pressure decrease along the ventilation airway in front of the seal lines.

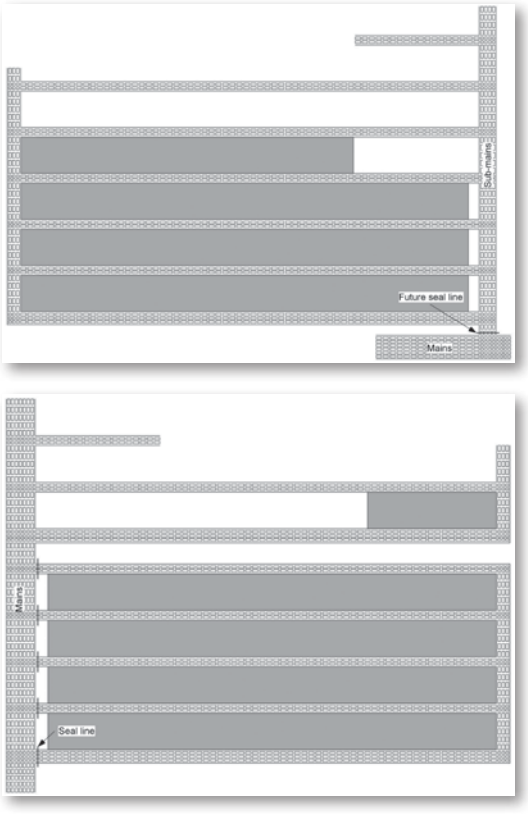
Several simple mining practices in the vicinity of future seals can lead to better seal construction, less seal leakage, and development of a permanently inert atmosphere within the sealed area. Figure 7 shows a typical mine layout in the vicinity of future seals near the mouth of a longwall panel and illustrates several desirable practices to consider:

1. Decrease the number of entries into panels: For longwall panels, the number of entries is usually three or four. For room-and-pillar panels, the number of entries should also be restricted to three or four as opposed to the total number of entries in the panel. Decreasing the number of entries along main entries to groups of panels may not be practical due to airflow requirements.
2. Increase the cross-cut spacing in the seal vicinity: This practice is most applicable to shallow-depth mines where the cross-cut spacing is less than 30 m (~100 ft). The maximum cross-cut spacing allowed by MSHA regulations is 200 ft (~60 m). Increasing the cross-cut spacing in the seal vicinity up to the maximum allowed will increase the pillar size and decrease the rock pressures in the seal area. During mining, it may be possible to skip making one cross-cut in the future seal area, if the normal cross-cut spacing is much less than 60 m (~200 ft).
3. Decrease the entry width in the immediate seal vicinity: Instead of cutting the entry 6 m (20 ft) wide as usual, consider cutting the entry 4.9 to 5.5 m (16 to 18 ft) wide if equipment size requirements permit. The increased pillar width will improve ground control, and less material may be required for seal construction.
4. Increase ground support in the area where seals will be constructed: Increasing the ground support (such as rock bolts and cable bolts) installed within about 15 m (50 ft) of the future seals will improve ground control in the area and decrease seal deterioration due to excessive rock pressure. The extra ground support will help prevent cracking and failure in the surrounding rock and decrease air leakage paths from the active mine into the sealed area.

Proper design and operation of the mine ventilation system around the sealed area can reduce seal leakage and help create a permanently inert atmosphere within the sealed area. The two major design principles to follow are to (1) minimize the pressure differential across seals and (2) increase the resistance across seals and seal lines. Both factors help decrease air leakage into a sealed area (ingassing) and prevent the formation of potentially explosive methane-air mixtures behind seals. In addition, both factors will also

Figures 5 and 6

Examples of longwall-mine layouts with simple seal layout that is less prone to leakage and promotes a safe, permanently inert atmosphere within the sealed area. Figure 5 – top: Simultaneous ingassing and outgassing across the single seal line is not likely. Figure 6 – bottom: Simultaneous ingassing and outgassing could occur between seal lines, but the flow would be small as long as the pressure decrease along the ventilation airway in front of the seals is small.



decrease the outflow (outgassing) of potentially explosive gases from sealed areas and decrease the gas load on the ventilation system.

Locating the seal line on a low-pressure split as shown in Fig. 8 can help minimize the pressure differential across seals. This low-pressure split ventilates past the seals and is near atmospheric pressure so that none of the seals are exposed to full – or nearly full – static fan pressure. Keeping most of the static fan pressure off the seals and seal line will minimize air exchange in or out of the sealed area. With an exhausting system, which is typical for most U.S. coal mines, a regulator is located downstream of the seal line and before the fan, as shown in Fig. 8. This regulator keeps most of the fan pressure off the seals to minimize leakage in or out of the sealed area. With a blowing system, the regulator would be located after the fan and upstream of the seal line.

Seals and seal lines will always experience some induced pressure differential from barometric pressure fluctuations due to diurnal variations and passing weather systems (Zipf and Mohamed, 2010), which will inevitably lead to air exchange in and out of sealed areas through the strata surrounding seals or some other pathway. It may be possible to decrease this pressure differential by controlling the methane withdrawal rate from surface boreholes into the sealed area. During periods of rising barometric pressure when seal lines tend to leak air into the sealed area, production from these surface boreholes should be slowed or stopped. Conversely, when the barometer is falling and seal lines are leaking gob gases from the sealed area into the ventilation system, production from these surface boreholes should be increased. By measuring the pressure differential across seals between the sealed area and the active mine, it may be possible to use that pressure measurement as a control signal for production from these surface boreholes.

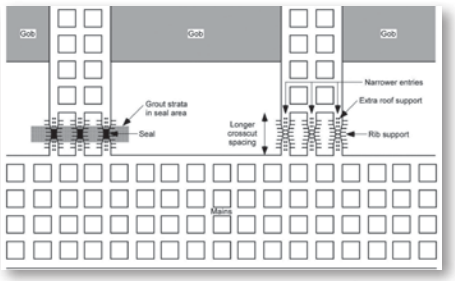
Increasing the resistance across seals and seal lines can help minimize this exchange. Grouting the strata surrounding seals as shown in Fig. 7 with cement grout, polyurethane or other products can slow the air exchange by filling the leakage pathways. Alternatively, shotcrete or other thin rock sealants can be applied to rock in the seal vicinity prior to seal construction.

Risk analysis for sealed-area explosions

Despite the fact that most sealed areas likely become inert and remain permanently inert after a few weeks, and therefore no longer pose an explosion danger, the data presented in Table 1 demonstrate that prior to 2006 many sealed areas did contain an explosive mixture and were ignited by some mechanism. Following the methods of Robertson and Shaw (2003), the risk posed by an explosion within a sealed area is evaluated in Fig. 9 by considering the likelihood of an explosion and the potential consequences of the explosion. The likelihood of an explosion might be described as known to happen in the industry or high with likelihood on the order of 1 to 10 percent chance of occurrence. The number of sealed-area explosions shown in Table 1 may represent about 1 percent of all the sealed areas in existence at the time. The consequences of an explosion within a sealed area can range from moderate, with cost of $100,000-1 million and resulting in no injuries and minor impact on operations, to extreme, with cost exceeding $10

Figures 7 and 8

Figure 7 – top: Suggested mine layout practices and ground control practices near seals that can decrease leakage and promote a safe, permanently inert atmosphere within the sealed area. Figure 8 – bottom: Suggested ventilation practice along seal line. Ventilating seals with a low pressure split results in lower differential pressure across seals, less leakage and the promotion of a permanently inert atmosphere within the sealed area.



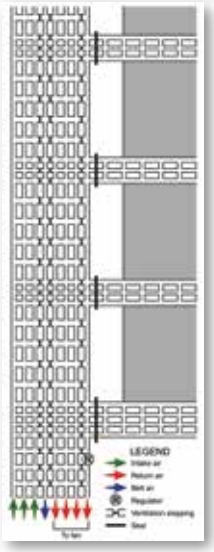


Figure 9

Risk analysis for sealed-area explosions before (solid line) and after (dashed line) the new seal regulations.

Consequence	Likelihood: Not likely < 0.01%	Low 0.01 to 0.1%	Moderate 0.1 to 1%	High 1 to 10%	Expected > 10%
Extreme – fatalities or multiple fatalities expected (> $10M)	Moderate risk	High risk	High risk	Critical risk	Critical risk
High – severe injury likely or fatality possible ($1-$10M)	Moderate risk	Moderate risk	High risk	High risk	Critical risk
Moderate – injury likely or severe injury possible ($0.1-$1M)	Low risk	Moderate risk	High risk	High risk	High risk
Low – first aid required or injury possible ($0.01-$0.1M)	Low risk	Moderate risk	Moderate risk	High risk	High risk
Negligible – no government or NGO attention likely (< $0.01M)	Low risk	Low risk	Moderate risk	Moderate risk	High risk

million and resulting in multiple fatalities and major impact on operations (Robertson and Shaw, 2003). Again, these consequences are supported by the sealed-area explosions data of Table 1. Therefore, the risk posed by an explosion within a sealed area might range from high to critical as indicated by the heavy solid line in Fig. 9, and that level of risk is unacceptable. Table 1 seems to support this evaluation for the risk posed by an explosion within sealed areas.

The risk analysis above reflects the circumstances before the enactment of the new seal regulations. Under the new seal regulations, the likelihood of an explosion within a sealed area that can breach seals may have decreased by an order of magnitude or more, placing the likelihood in the low category with 0.01 to 0.1 percent chance of occurrence or possibly the "not likely" category, with less than 0.01 percent chance of occurrence. While the consequences of an explosion within a sealed area have not changed, the risk has decreased from the high to critical range to the moderate to high range, as indicated by the heavy dashed line in Fig. 9. This level of risk may be considered acceptable.

Summary

The Final Rule on Sealing of Abandoned Areas of Coal Mines focuses on seal designs to contain a potential explosion within a sealed area. Anecdotal evidence suggests that most sealed areas become inert and remain permanently inert soon after sealing. However, scientific data on sealed-area atmospheric compositions for a wide range of different conditions are lacking.

Prior to the Final Rule, certain sealing practices may have contributed to the development of potentially explosive atmospheres within sealed areas. Long, complex seal lines that simultaneously ingas in one area and outgas in another were problematic and could have led to the formation of explosive methane-air mixtures within the sealed areas. Mines at shallow depth with low methane inflow rate and low oxidation rate continue to be problematic since an explosive methane-air mixture can accumulate and persist for a long time.

Engineering techniques to promote the development of safe, permanently inert atmospheres within sealed areas include: (1) better overall mine layouts that minimize the number of seals, (2) better mining practices in the area where seals will be constructed that improve ground control and decrease leakage into sealed areas and (3) better ventilation system design to minimize air exchange entering or exiting sealed areas. Use of these techniques may allow the use of more economical 345-kPa (50-psi) seals if the proper monitoring protocol is followed. The development of permanently inert atmospheres within sealed areas by engineering design may lead to further decreases in the risk from sealed-area explosions. ■

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Reliability analysis of hydraulic shovels

by S.R. Dindarloo and E. Siami-Irdemoosa

Abstract ■ Pareto analysis was used to investigate the failures database of a Hitachi EX1900 hydraulic shovel over one year of continuous operation. The hydraulic system and hydraulic links, hoses and piping were identified as the most critical system and subsystem, respectively. A three-parameter gamma distribution function was identified as the best fit for a probabilistic modeling of the time between failures (TBFs). This distribution was used in a Monte Carlo reliability analysis of the hydraulic system. Autoregressive integrated moving average (ARIMA), within the context of a time series analysis of the TBFs, was proposed as a viable alternative to the traditional technique of distribution fitting. The mean absolute percentage error (MAPE) metric was used to compare the two models. The MAPE value that resulted from the ARIMA was 66 percent smaller than that from the traditional technique in predicting the TBFs.

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Resumen ■ Se usó análisis Pareto para investigar la base de datos de fallas de una pala hidráulica Hitachi EX1900 durante un periodo de un año de operación continua. Se identificó al sistema hidráulico y a los enlaces hidráulicos, mangueras y tuberías como el sistema y subsistema más importantes, respectivamente. Se identificó una función de distribución de tres parámetros gamma como el más apto para un modelado de probabilidades del tiempo transcurrido entre las fallas (Tabes por sus siglas en inglés). Esta distribución fue usada en un análisis de confiabilidad Monte Carlo para un sistema hidráulico. El promedio de movimiento integrado auto-regresivo (ARIMA por sus siglas en inglés), dentro del contexto de análisis de serie temporal de los TBFs, fue propuesto como una alternativa viable a la tradicional técnica de ajuste de distribución. Se usó el porcentaje de la media absoluta de error (MAPE) para comparar los dos modelos. El valor MAPE que resultó de la ARIMA fue 66 por ciento menor que el resultado obtenido con la técnica tradicional de predicción de TBFs.

S.R. Dindarloo and E. Siami-Irdemoosa, members SME, are Ph.D. candidates at the Department of Mining and Nuclear Engineering and Department of Geosciences and Geological and Petroleum Engineering, respectively, at the Missouri University of Science and Technology, Rolla, MO. **Paper number TP-14-044. Original manuscript submitted September 2014. Revised manuscript accepted for publication January 2015. Discussion of this peer-reviewed and approved paper is invited and must be submitted to SME Publications by Dec. 31, 2015.**

Accurate estimates of reliability indices are of increasing importance to reliability-related decision-making industries. The advanced knowledge of reliability information would allow for more accurate forecasts of spare requirements, support costs and warranty costs and hence the initiation of appropriate preventive and corrective maintenance plans. Traditionally, failure data analysis requires not only the specification of parametric failure distributions but also the justification of certain assumptions that are at times difficult to validate. The reliability index's data, such as the time between failures and the number of failures per time interval, should be independent and identically distributed. Normality is another important assumption. In addition, only reliability measures in some fixed time interval are predicted. Thus, it is not easy to forecast the variability of reliability indices with time (Xu et al., 2003). The time series analysis of the time between failures (TBFs) is a viable alternative to traditional techniques such as fitting probability distribution functions. The autoregressive integrated moving average (ARIMA) models time series data by constructing a linear relationship between past observations, errors (residuals), and current data. No a priori postulation of the models is required in ARIMA, so the restrictions of the traditional tech-

niques are not imposed (Ho and Xie, 1998).

Su et al. (1997) proposed a hybrid model of ARIMA and artificial neural networks for predicting a system's reliability, while Chatterjee et al. (2011) used ARIMA to predict software reliability. Amin et al. (2013) compared ARIMA with software reliability growth models (SRGMs) and obtained better modeling and prediction results from ARIMA than from SRGMs. Gorlov and Strogonov (2007) used ARIMA to predict integrated-circuit failures.

In this study, both the Monte Carlo reliability and ARIMA (Box-Jenkins model) techniques were applied to the failure database of the hydraulic system and subsystems of a mining

Table 1

Descriptive statistics of the TBF data (in hours).

Count	Mean	StDev	Q1	Median	Q3	Minimum	Maximum	Skewness	Kurtosis
55	134.00	130.69	20.88	109.21	191.35	0.32	577.76	1.24	1.52

Table 2

Raw data.

	Observation #	TBF	SARIMA	Residual
Model training	1	52.903	52.903	0.000
	2	1.871	1.871	0.000
	3	109.210	109.210	0.000
	4	9.161	9.161	0.000
	5	56.777	56.777	0.000
	6	56.580	131.155	-74.575
	7	16.422	8.063	8.360
	8	157.443	83.612	73.831
	9	95.524	145.049	-49.526
	10	12.024	79.778	-67.754
	11	106.299	109.407	-3.108
	12	4.862	120.969	-116.106
	13	6.672	5.666	62.338
	14	241.894	87.671	154.224
	15	148.841	123.624	25.218
	16	1.162	86.232	-85.070
	17	124.017	225.372	-101.356
	18	2.551	88.538	-85.987
	19	163.428	6.055	222.483
	20	22.136	163.052	-140.916
	21	577.764	68.628	509.136
	22	405.647	348.637	57.010
	23	20.880	311.105	-290.225
	24	134.000	428.313	-294.313
	25	66.114	223.017	-156.903
	26	21.638	79.802	-58.165
	27	81.211	51.413	29.797
	28	179.092	272.638	-93.546
	29	191.354	47.630	143.725
	30	183.893	222.905	-39.011
	31	340.403	18.426	321.977
	32	0.322	25.853	-25.531
	33	167.344	181.007	-13.663
	34	229.857	256.090	-26.232
	35	14.674	100.301	-85.627
	36	49.519	200.547	-151.027
	37	142.291	222.115	-79.824
	38	449.759	65.532	384.227
	39	2.687	97.952	-95.266
	40	248.618	202.366	46.252
	41	276.676	247.840	28.836
	42	24.874	118.737	-93.863
	43	123.333	193.822	-70.489
	44	12.693	162.670	-149.977
	45	224.213	124.916	99.296
Model testing	46	224.21	130.187	94.026
	47	124.52	185.337	-60.822
	48	25.26	35.181	-9.923
	49	361.48	148.802	212.676
	50	185.48	124.293	61.184
	51	178.40	175.000	3.397
	52	298.21	162.755	135.459
	53	329.25	81.665	247.583
	54	212.24	66.536	145.705
	55	82.76	55.020	27.741

hydraulic shovel. The objective of the study is to examine applicability of the ARIMA technique in predicting the future TBFs of only the hydraulic system and subsystems, using the historical data of failures over one year of operation.

Methods and materials

The three major reliability indices used to analyze repairable systems are: (1) time between failures (TBFs) or time to failures (TTFs), (2) time to repair (TTR) and (3) number of failures per time interval (NF). Pareto analysis (Hall et al., 2000) was used to analyze the failure data of a Hitachi EX1900 hydraulic shovel. The hydraulic system was identified as the most critical system in terms of failure frequency and TBFs. Similarly, the hydraulic links, hoses and piping were identified as comprising the most critical subsystem. Descriptive statistics of the TBF data are shown in Table 1.

The shovel's failure database, maintained over one year of continuous operation, included 55 records of hydraulic failures (Table 2). A three-parameter gamma distribution was fitted to the TBF histogram (Fig. 1). The first 45 data points were used for PDF fitting (training dataset), and the remaining 10 were used for model testing. Minitab statistical analysis software was used to determine the best fit. The shape, scale and threshold parameters of the best fit were determined as 0.69, 179.2 and –0.289, respectively. The maximum p value among 14 theoretical distributions was used to select the best fit. Trend and autocorrolation of the dataset were evaluated using the Mann-Kendall trend test and the correlograms of Figs. 2 and 3, respectively. As depicted in Fig. 4, there is no trend in the TBF dataset. In the Mann-Kendall trend test, the S statistic used for the test and its variance is given by:

$$S = \sum_{i=1}^{n-1} \sum_{j=j+1}^{n} \mathrm{Sgn}(x_j - x_i) \quad (1)$$

$$\mathrm{Var}(S) = \frac{n(n-1)(2n+5)}{18} \quad (2)$$

where n is the number of observations and x_i $(i = 1,\ldots,n)$ are the independent observations.

The Mann-Kendall trend test requires that the observations are independent, meaning the correlation between the series and itself with a given lag should not be significant (Figs. 2 and 3).

The temporal diagram of TBFs is expected to show a decreasing trend due to fatigue, aging and the mechanical tear and wear of different components. However, in this study, only the TBFs for one year of shovel operation were studied. Thus, no noticeable decreasing trend was seen on inspection in the diagram of Fig. 4.

ARIMA. The autoregressive integrated moving average (ARIMA) models developed by Box and Jenkins (1970) provide a robust approach to time series forecasting. Exponential smoothing and ARIMA models are the two most widely used approaches in time series forecasting, providing complementary solutions to time series forecasting. Exponential smoothing models are based on a description of trend and seasonality in the data. The ARIMA models, however, are used to describe autocorrelations that exist within the data (Hyndman and Athanasopoulos, 2013). An ARIMA model is, essentially, a data-oriented approach that is adapted from the data structure (Pai and Lin, 2005). Forecasting is based on a linear combination of past observations that need a stationary series without any specific trend in the data. The future value of a variable in an ARIMA model is supposed to be a linear combination of past values and past

Figure 1

Three-parameter gamma distribution of TBF.

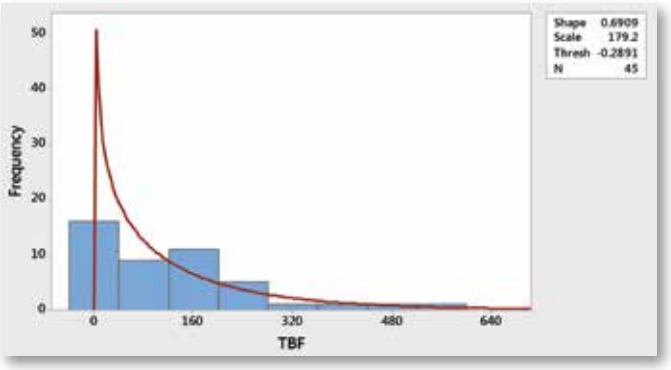


Figure 2

Autocorrelation diagram.

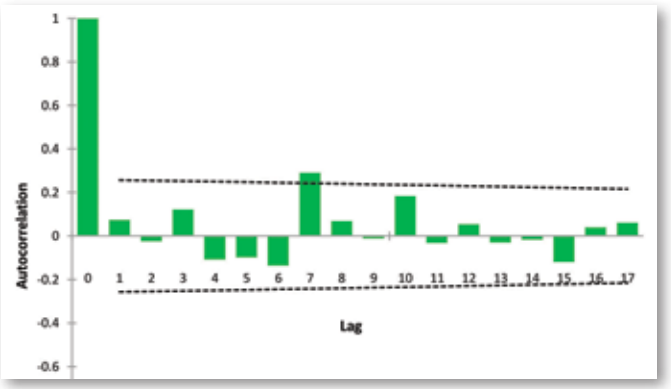
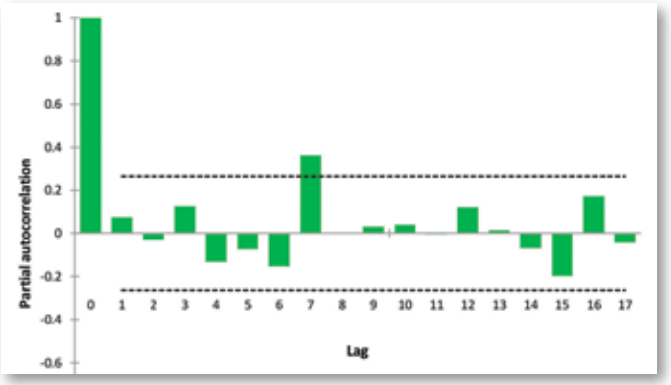


Figure 3

Partial autocorrelation diagram.



errors, expressed as:

$$y_t = \vartheta_0 + \varphi_1 y_{t-1} + \varphi_2 y_{t-2} + \cdots + \varphi_p y_{t-p} + \varepsilon_t - \vartheta_1 \varepsilon_{t-1} - \vartheta_2 \varepsilon_{t-2} - \cdots - \vartheta_q \varepsilon_{t-q} \quad (3)$$

where y_t is the actual value, ε_t is the random error at time t, and φ_i are ϑ_i the coefficients, and p and q are integers that are often referred to as autoregressive and moving average polynomials, respectively. For example, the ARIMA(1,0,1) model can be represented as:

$$y_t = \vartheta_0 + \varphi_1 y_{t-1} + \varepsilon_t - \vartheta_1 \varepsilon_{t-1} \quad (4)$$

A central feature in the development of time series models is an assumption of some form of statistical equilibrium. A particular assumption of this kind is that of stationarity. A stationary time series can be usefully described by its mean, variance and autocorrelation function (ACF) (Box et al., 2008).

The internal correlation of the observations in a time series is usually expressed as a function of the time lag between observations. The autocorrelation at lag k, $\gamma(k)$, is defined as:

$$\gamma(k) = \frac{E(X_t - \mu)(X_{t+k} - \mu)}{E(X_t - \mu)^2} \quad (5)$$

where X_t, $t = 0, \pm1, \pm2, \ldots$ represents the values of the series, μ is the mean of the series, and E is the expected value. A plot of the autocorrelation's sample values against the lag is known as the autocorrelation function, or correlogram. A correlogram is a basic tool in the analysis of time series, particularly for indicating possibly suitable models (Everitt, 2002). Figure 2 shows an auto-correlogram of the TBFs. The "suspension bridge" pattern is a typical characteristic of both nonstationary and seasonal time series. The time lag here is one step in the failures order. For example, the time between the failures #51 and #52 is 178.4 hours (Table 2). This is equal to one lag. In time series analysis and prediction, one needs to know if there is any correlation between the current value and the one before (lag = 1) and/or the two preceding observations (lag = 2), and so on. Partial autocorrelations (PACFs) measure the degree of association between various lags when the effects of other lags are eliminated (Fig. 3). Both ACF and PACF are primary graphical tools that are used to inspect a time series. They are also used to determine the order of autoregressive and moving average components of the model. The parameters illustrated in Figs. 2 and 3 were used in this study to identify a class of candidate models. The Akaike Information Criterion (AIC) (Akaike, 1974), with minimum value, was used to select the optimal model among the candidate ones that were examined in the previous step.

The application of differencing is often used to transfer data into a stationary series. One or two orders of differencing are typically enough to prepare data for the method. The combined autoregressive-moving average model in this case, that is, ARMA(p,q), is referred to as ARIMA(p,d,q), in which parameter d is the differencing order. A seasonal pattern occurs in the data illustrated in Fig. 4. The application of ARIMA in seasonal data needs further differencing in the seasonal portion. In this case, the model is known as seasonal autoregressive integrated moving average (SARIMA), and it is represented by SARIMA(p,d,q)(P,D,Q)$_S$, with a seasonal differencing order of D and a cycle of S. The P and Q represent the autoregressive and moving average components of the seasonal part of data, respectively. D = 1 was used to address the model's seasonality. The AIC was used to select the SARIMA model's best p, q, P and Q as SARIMA(3,2,2)(1,1,0)$_3$. In Table 3, AR(1) is the first coefficient of the autoregressive component of the model. Simi-

Figure 4

SARIMA model: Training and prediction versus actual data.

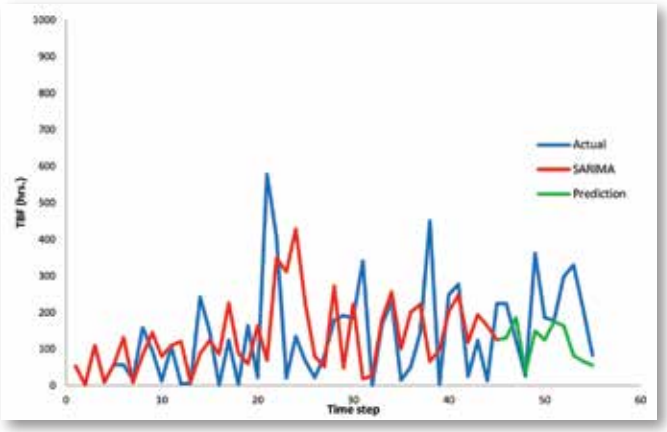


Figure 5

Scattergram of actual TBFs versus SARIMA prediction.

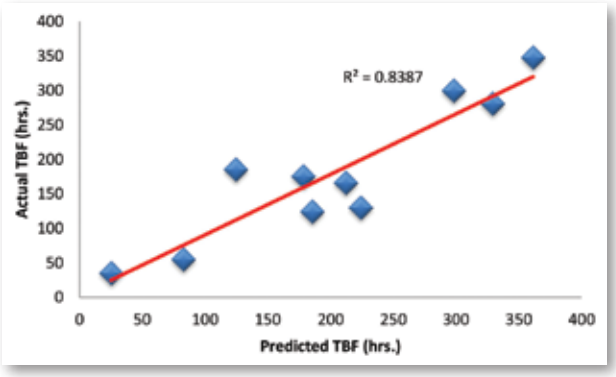


Figure 6

Scattergram of actual TBFs versus gamma distribution.

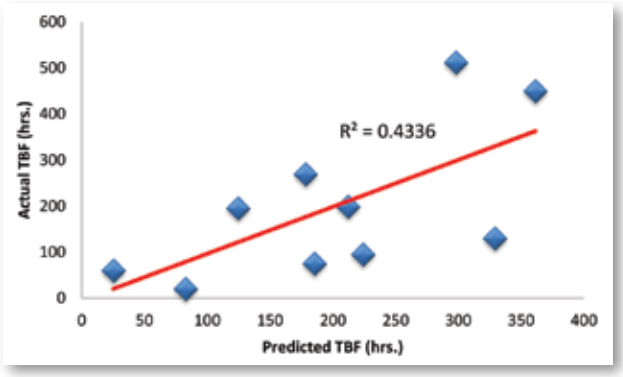


Figure 7

Training model's residuals.

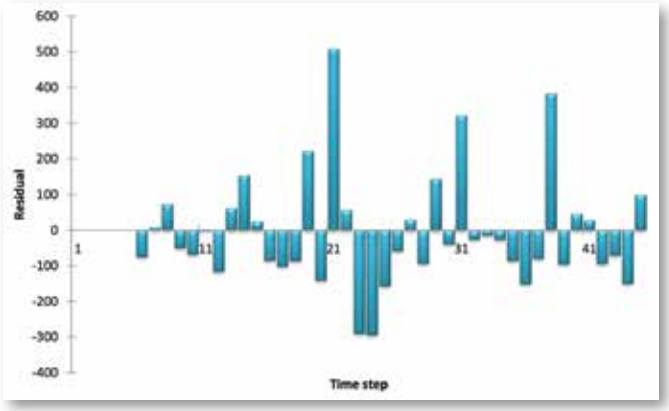
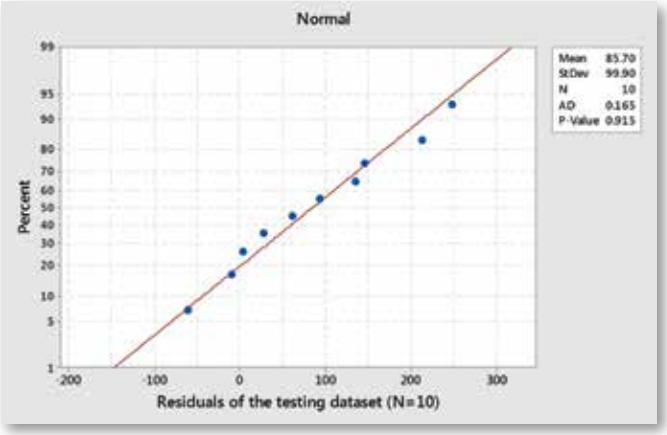


Figure 8

Testing residuals normality test.



larly, AR(2) and AR(3) represent the second and third coefficients. SAR(1) is the coefficient of the seasonal part of the autoregressive component. MA(1) and MA(2) are the first and second coefficients of the moving average components of the time series model. Both the Hessian and asymptotic errors of all coefficients were calculated and listed in Table 3. The result of the optimal SARIMA in both modeling and predicting the training and testing datasets, respectively, are illustrated in Fig. 4. Of 55 TBF records, 45, or 82 percent, were used for model training (building) and the remainder, or 18 percent, for model testing. The mean absolute percentage error (MAPE) value for the testing dataset was calculated as 44.6 percent. The scattergrams of the SARIMA and gamma predictions versus the actual observations for TBFs are presented in Figs. 5 and 6, respectively. The coefficient of determination (R^2) obtained for the SARIMA model (0.84) is considerably superior to that of the Monte Carlo simulation using gamma distribution (0.43).

A SARIMA model has three basic phases: model identification, parameter estimation and diagnostic checking. Running a model diagnostic is the last SARIMA modeling task that can be performed by inspection of residuals as well as application of statistical metrics, such as MAPE, to both the predicted and the observed values. The Ljung and Box (1978) test was used to examine the residuals (illustrated in Fig. 7) for satisfaction of the white noise series condition. A white noise series is a sequence of statistically independent and identically distributed random variables. The result of Anderson-Darling normality test for residuals of the testing (prediction) dataset (N = 10) is illustrated in Fig. 8. The obtained P-value is greater than 0.05, so the null hypothesis of the residuals normality should not be rejected.

Table 3

SARIMA model: Parameters.

Parameter	Value	Hessian standard error	Asymptotic standard error
AR(1)	–0.599	0.218	0.131
AR(2)	–0.460	0.172	0.152
AR(3)	–0.758	0.079	0.166
SAR(1)	–0.758	0.079	0.166
MA(1)	–1.099	0.321	0.181
MA(2)	0.099	0.311	0.181

Discussion

To test the accuracy of TBF prediction using the best probability function fitted, that is, the gamma three-parameter, 10 random numbers were derived from the distribution and compared with the last 10 actual TBF data through the MAPE metric. The procedure was repeated 2,000 times using the Monte Carlo simulation technique. The MAPE's mean and standard deviation were calculated as 138.43 and 15.78 percent, respectively. A time series analysis of TBFs produced optimized model parameters (Table 3). SARIMA$(p,d,q)(P,D,Q)_S$ at a confidence interval of 95 percent, with 500 iterations that used maximum-likelihood optimizations, produced SARIMA$(3,2,2)(1,1,0)_3$ (Figs. 2 and 3). The Monte Carlo simulation's average MAPE value of 138.43 percent conducted for 2,000 replications, with each replication containing 10 random TBF numbers, was compared with the MAPE calculated from the SARIMA model (44.6 percent). This comparison revealed that SARIMA outperformed the method of simulation. An essential requitrement of a successful Monte Carlo reliability analysis is to provide a representative probability distribution by collecting a large amount of historical data. In this study, the failures over only one year of operation were available (N = 55). Of the available 55 datapoints, 10 were used for model testing and 45 were used for estimating the best fit. Consequently, the Monte Carlo sampling from the proposed PDF did not result in reasonably accurate estimates for the testing dataset. The alternative model does not need PDFs and directly constructs a mathematical model on the historical dataset. Thus, the relatively small amount of training data was not a major hurdle as it was in the simulation.

Conclusions

The hydraulic links, hoses and piping of a Hitachi EX1900 shovel were identified as comprising the most critical hydraulic subsystem in terms of failure frequency and TBFs. The best PDF function (three-parameter gamma) was fitted to the histogram of the subsystem's TBFs. A Monte Carlo reliability analysis was conducted using the proposed PDF. Moreover, the optimal parameters of SARIMA for modeling the TBFs were determined. SARIMA$(3,2,2)(1,1,0)_3$ outperformed the conventional PDF fitting with a MAPE value of 44.6 percent. This was more than 66 percent smaller than the MAPE value of 138.43 percent obtained from the three-parameter gamma distribution. Thus, time series modeling of TBFs is a viable alternative to the traditional techniques used in the reliability analysis of mining hydraulic shovels. ■

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SME seeks nominations for Distinguished Members

The SME Distinguished Member award was initiated in 1975. It honors those members who achieve distinction worthy of special recognition by SME. No more than four Distinguished Members may be elected each year, excluding the automatic election of the SME past president.

Nominations must be made by Dec. 1 of each year. The Distinguished Member Award Nominating Committee meets during the SME Annual Meeting to select up to four nominees, and the SME Board of Directors formally approves the awards. The biographies and photos of the chosen Distinguished Members are published in *Mining Engineering* and the awards are presented at the following SME Annual Conference. A nomination is active for three years.

Eligibility requirements

A candidate for Distinguished Member must have been a full-member of SME for at least 15 years. A candidate must have demonstrated significant and sustained contributions to the minerals industry and to SME. There must be some contributions to both the industry and SME, though significant and sustained contributions can be to either one.

Outstanding service to SME may be to a section, a region, a technical division, committees or as a representative of SME and the industry to the public. Outstanding contributions to the industry may be as a leader in exploration, production, manufacturing, environment, basic sciences, engineering applications, education, management or public relations. This may be evidenced by patents, technical papers, educational activities or managerial contributions. Other contributions may be in the development of exploration techniques, mineral properties, mineral processes, major engineering projects, mineral-related equipment and environmental solutions.

Members receiving this award must attend the annual conference to accept the honor at the SME dinner.

Candidates may be nominated by any two SME Distinguished Members (each knowing the member under different circumstances), any two local section executives (must include a chair or past chair) or five members of SME.

Nomination procedure

All nominations for the Distinguished Member class of 2017 must be received by SME by Dec. 1, 2015. The nomination form for a Distinguished Member must include the following information: nominee's full name, biography and a concise statement that demonstrates the nominee's sustained contributions to SME and to the minerals industry. List examples such as patents, technical papers, educational activities and managerial contributions.

Only printed nomination forms will be accepted. And nominations should not exceed four printed pages. A paper or electronic version of the nomination form may be obtained from the Member Services Department, SME, 12999 E. Adam Aircraft Cir., Englewood, CO 80112, phone 800-763-3132 or 303-948-4230, email grace@smenet.org. ■

SME Distinguished Members

John F. Abel Jr.
Dan Alexander
Mark A. Anderson
Frank F. Aplan
Barbara J. Arnold
James R. Arnold
Timothy D. Arnold
George S. Austin
Leonard G. Austin
Sukumar Bandopadhyay
James M. Barker
Robert W. Bartlett
William J. Beck
Roshan B. Bhappu
Rodney L. Bleifuss
James W. Boyd
Severn P. Brown
Jurgen F. Brune
Charles H. Bucknam
Richard L. Bullock
Alan A. Campoli
William Carr
Yoginder (Paul) Chugh
Arthur F. Colombo
Harry M. Conger
Kadri Dagdelen
Maurice Deul
Edward C. Dowling Jr.
Joe Driscoll
James R. Dunn
Ted H. Eyde
Thomas V. Falkie
George J. Featherstone
Barbara A. Filas
William G. Fischer
Robert C. Freas
Edward S. Frohling
John E. Frost
Douglas W. Fuerstenau
Richard E. Gray
Thomas A. Gray
R. Larry Grayson
Kenneth N. Han
Bill A. Hancock
Ronald O. Harma
Leonard Harris
Laurence D. Hartzog
Raymond Henn
J. Brent Hiskey
Steven C. Holmes
Rick Q. Honaker
Winfred L. Hurley
William Hustrulid
G. Frank Joklik
Leonard R. Judd
Michael Karmis
S. Komar Kawatra
Jessica Elzea Kogel
Jeffrey Kohler
Martin C. Kuhn
Ihor A. Kunasz
K. Marc Le Vier
Joseph W. Leonard III
Ta M. Li
Raymond L. Lowrie
Gerald H. Luttrell
George W. Luxbacher
Deepak Malhotra
David R. Maneval
John G. Mansanti
John O. Marsden
Francis Martino
Michael K. McCarter
Gene E. McClelland
Robert C. Merritt
Drew A. Meyer
E. J. Michal
Hugh B. Miller
Jan D. Miller
John D. Morgan
Brij M. Moudgil
Siegfried Muessig
John N. Murphy
Haydn H. Murray
Robert E. Murray
Jan M. Mutmansky
D.R. Nagaraj
Thomas J. O'Neil
Timothy G. O'Neil
Bhupendra K. Parekh
Harry M. Parker
Syd S. Peng
William C. Peters
Mary M. Poulton
William N. Poundstone
Raja V. Ramani
Donald E. Ranta
Ramana G. Reddy
Jean-Michel M. Rendu
Richard J. Robbins
Lee W. Saperstein
Kalanadh V. S. Sastry
Robert W. Schafer
William Joseph Schlitt
John L. Schroder Jr.
Arthur A. Schweizer
Rohini P. Sharma
William M. Shepard
Robert S. Shoemaker
Douglas B. Silver
Madan M. Singh
Raj K. Singhal
Ponisseril Somasundaran
Stanley C. Suboleski
David A. Summers
Patrick R. Taylor
Jack E. Thompson
Michael A. Trevits
Nikhil C. Trivedi
William A. Warfield
Ronald L. Wiegel
William H. Wilkinson
Kelvin K. Wu
Richard V. Wyman
Roe-Hoan Yoon

SME programs provide the tools to advance the industry

by Dennis Bryan, SME Foundation President

As you know, our industry is facing difficult and challenging times. As an SME member, your support and participation is needed now more than ever to secure the future of mining and the SME Foundation. SME programs provide the tools and resources for advancing the industry.


BRYAN

You can help us change the public perception of mining and create the next generation of professionals.

Membership dues renewals will be in the mail soon. By investing a minimum of $15 on your annual dues bill, just an additional 10 percent of the dues you pay to the Society, the Foundation can maintain crucial programming. Or, you can consider becoming a Legacy Club member. The club honors those who have invested in SME's future by including the SME Foundation as a named beneficiary in their estate plans. Additional information can be found at www.smefoundation.org.

New SMEF programs

One exciting new program is the Ph.D. Fellowship and Career Development Grant. This program addresses the absence of a viable pipeline to replenish current faculty vacancies and the looming labor deficiencies associated with retirements over the next decade in U.S. mining schools. The Ph.D. Fellowship focuses on providing financial support to encourage qualified candidates with industry experience, and a desire to pursue an academic career, with the means of acquiring a doctoral degree in the field of mining engineering, mineral processing or extractive metallurgy at a U.S. accredited university. The Academic Career Development Grant provides tenure-track assistant or associate professors with the financial support needed to better participate in activities such as research, publication and professional service, which are necessary to achieve tenure and promotion.

Additional programs of the SME Foundation include:

- ABET accreditation program recruits, trains and deploys professionals who visit colleges or universities that offer degrees in mining engineering fields to ensure the programs maintain the ABET accreditation.
- Professional Engineers (PE) Exam program — SME is the only organization in the United States that prepares examination questions for the licensure of mining and mineral processing engineers. PE licensure is the gold standard for professional competency.
- The Minerals Education Coalition is positioning itself to be a clearinghouse for all relevant K-12 STEM education about minerals and mining. It is a resource for developing new curricula to fill identified gaps in the K-12 educational spectrum and an outreach resource for volunteer advocates in K-12 classrooms and for teachers via NSTA conferences.
- The Miners Give Back program has partnered with Engineers Without Borders, an organization with a long history of providing global outreach through sustainable engineering projects. Miners Give Back is committed to supporting worldwide initiatives focused on humanitarian efforts. The goal is to tangibly contribute to improving the lives of individuals on a global level.
- Endowed scholarships:
  J.H. Fletcher & Co. Scholarship.
  McIntosh Engineering Scholarship Fund.
  Ernst K. Lehmann Memorial Scholarship for geological studies.
  MMSA/SMEF Presidential Scholarship.
  Syd & Felicia Peng Ground Control in Mining Scholarship and Award.
  Rong-Yu Wan Scholarship.

As an SME member, I'd like to ask you to invest in your profession by making a contribution to the SME Foundation at www.smefoundation.org. Together we can accomplish great things.

Many thanks,
Dennis P. Bryan
SME Foundation President ■

Personal News


KECOJEVIC

VLAD KECOJEVIC (SME), professor of mining engineering and Massey Foundation professor at West Virginia University, was appointed as the 2015-2016 president of the Society of Mining Professors/Societat der Bergbaukunde at its annual meeting and conference, held in Freiberg, Germany, June 2015. The Society of Mining Professors (SOMP) is a global society, with members in 43 countries, representing mining and mining-related academics. The main purpose of SOMP is to promote mining engineering as an engineering discipline, to facilitate information exchange, research and teaching collaboration, and other collaborative activities among its members. Kecojevic will lead the next SOMP annual meeting and conference in Washington, D.C., September 2016. *(Continued on page 73)*

Back to school with MEC

by Rachel Grimes, MEC Outreach Coordinator

The Minerals Education Coalition's (MEC) mission is to provide education and outreach resources in an effort to help create an enlightened and supportive public that appreciates the importance of mining and minerals to their lives. MEC will increase its K-12 educational offerings by collaborating with geoscience organizations and offer all resources at www.MineralsEducationCoalition.org. MEC relies on SME members to help spread the word to local classrooms and community groups about the importance of mining and minerals.

MEC clearinghouse of educational resources

MEC works to find the best available materials that meet key educational criteria and then provides those materials to teachers through its website. To find and offer these materials, MEC collaborates with other organizations that provide excellent educational materials about mining and minerals that are technically accurate, industry relevant, grade appropriate, meet state and national educational standards, and cover a broad spectrum of mining and minerals content. These existing materials may be hosted or linked on MEC's K-12 webpages, or offered at a low cost in MEC's online store.

Materials that have been vetted and added to our website since the project's inception include outstanding educational activities for grades K-12 from Caterpillar, Freeport-McMoRan Copper and Gold, the U.S. Geological Survey, Mining Matters (Canada), Rio Tinto (Australia), the National Energy Foundation, Rio Tinto Utah Kennecott Copper and the Nevada Mining Association. MEC thanks these organizations for sharing their excellent resources with our audiences and thanks our other collaborators whose materials will be placed on our website soon.

EdGate Correlation Services

MEC has also contracted with EdGate Correlation Services. Through EdGate, MEC materials will be correlated with the full array of Next Generation science standards, Common Core state standards in language arts, math and social sciences, including geography, history and economics, and all state standards. The correlations will be made by curriculum experts and kept up-to-date.

An especially exciting aspect of the services that EdGate provides is a searchable website tool. Teachers will be able to search all MEC curriculum materials by subject and standard through this tool on the MEC website. The first set of MEC materials is being correlated now and will be available online Oct. 1, in time for the new school year. Using EdGate is an exciting way to improve the educational functionality of the MEC website for teachers.

K-12 students learn about the importance of mining and minerals using MEC educational resources.

MEC already offers more than 100 free and low-cost educational activities, videos, demonstrations, posters, presentations and kits. Now, more than 100 additional activities, videos, presentations and animations have been added through the clearinghouse project. MEC's offerings will continue to grow through time and, with the education standards correlation tool from EdGate, teachers heading back to school this fall will be able to visit one website for diverse resources to use in teaching K-12 students about the importance of minerals and mining. ■

Volunteers needed for 2015 NSTA area conferences

Again in 2015, MEC will partner with local SME members, sections, student chapters and other local businesses and organizations to provide free rock and mineral kits to educators at the National Science Teachers Association (NSTA) area conferences. Volunteer conference committees are currently meeting to organize the details of creating, storing and distributing 1,500 rock and mineral kits and thousands of educational posters.

2015 NSTA Area Conferences will be held:

- Oct. 22-24, Reno, NV.
- Nov. 12 -14, Philadelphia, PA.
- Dec. 3-5, Kansas City, MO.

If you are located in these areas and would like to volunteer your time to staff the booth, we would love to have you. Booth staff will hand out rock and mineral kits and posters to educators and talk to them about the importance of mining and minerals in everyday life. If you are not located near an NSTA area conference location but would like to attend a science teachers' conference, attend your

(Continued on page 72)

Mineral industry challenges

The chemistry elephant in the room

by D.R. Nagaraj and R.S. Farinato

Current challenges in the mineral processing industry are well expressed in the literature: processing low-grade and poor-quality ores, improvements in water usage efficiency and water resource management, waste reduction and remediation, complying with and exceeding increasingly restrictive HSE regulations, the need for more environmentally benign chemicals, minimizing overall environmental impact, and better energy efficiency. These challenges are very broad, complex and independent of the industry boom and bust cycles. They are linked to the three pillars of sustainability — societal, environmental and economic — which rely heavily on technological, rather than traditional economy-of-scale solutions, generally engineering-based and/or chemistry-based. We focus on the latter, because they highlight unique disparities, importance versus lack of application knowledge and industry acceptance, which must be fixed to address sustainability challenges in a meaningful way.

Chemical aspects of flotation

Chemistry-based solutions will undoubtedly play a pivotal role in addressing most of these challenges. Independent of whether these solutions require the development of new, or the implementation of existing, technologies, successfully addressing the challenges will require robust application knowledge and technology acceptance by the mineral processing industry. Unfortunately, currently we have problems with both.

The application knowledge base and research framework, from which such knowledge is generated, are both outdated and inadequate. When naturally complex problems are modeled as idealized systems (i.e. a reductionist approach), too often the results are simplistic and irrelevant. Fragmentary and uncoordinated research efforts compound the issue. A prime example may be found in flotation.

Modeling flotation has been a lofty goal for many decades. While significant advances have been made in modeling the physical-mechanical aspects of flotation, the absence of chemical aspects is a particularly glaring omission given that successful flotation is leveraged through interfacial chemistry, which, in turn, is affected by mineral-solution chemistry. Almost all flotation models either ignore chemistry or collapse it into a single number (contact angle), where it is convoluted with a panoply of other nonchemical factors. This is the equivalent of characterizing a population of people by their hat size.

Flotation models might be improved by invoking richer parameterization of the contact angle, e.g. accounting for contact angle distributions, taking into account spatial heterogeneity and/or dynamical aspects in the bubble-particle contact process. However, this still buries chemical factors among a host of physical factors, and it neglects kinetics aspects of the chemically evolving system (e.g. mineral dissolution, hydrolysis, surface oxidation and reagent reactions).

In addition to the difficulty of accounting conceptually for more realistic chemistry, we are faced with the even greater challenge of determining quantitative parameter estimates that characterize this chemical complexity. In situ methods for analyzing the mineral-solution interface during a bubble-particle collision in a turbulent fluid are not currently available. However, this should not deter efforts in the research community to develop and incorporate a more robust set of chemical factors into flotation models to make them meaningful and useful. This should be the new goal. Other fields with similar chemical complexity have made considerable progress. It must be recognized, however, that developing these more complete models would be fruitful only when operations are motivated to make necessary changes based on the insights gained.

Health, safety, environment

Among the challenges listed above, the HSE and regulatory aspects loom large, accentuated by the ambiguity and tepidity with which we acknowledge and approach this elephant in the room. More restrictive regulations are inevitable because of increasing expectations from society and a genuine concern for improving HSE.

Chemical companies have experienced a dramatic increase in more stringent regulations for chemicals, well in advance of the mineral industry, and many leading chemical companies have fully incorporated HSE into their technology portfolio. The regulatory landscape is rapidly changing and becoming more complex, eventually impacting the mining industry.

Fine Grind **serves as a forum for the presentation and discussion of facts, ideas and opinions pertaining to the interests and technology of the Mineral & Metallurgical Processing Division. Accordingly, all material published herein is signed and reflects the individual views of the authors. It is not an official position of SME or the division. Comments by readers will be referred to the division for response. The division chair in 2015 is Richard H. Johnson.**

Given the large amounts and types of chemicals used in mineral processing, many of which are hazardous, HSE aspects are of critical importance. This should drive the adoption of safer and more environmentally friendly chemicals, if they already exist, or the development of new ones — a major challenge in itself. In either case, acceptance by industry is the key.

Some operations have already begun to make changes. Many operations, however, prefer the current paradigm,

(Continued on page 72)

2015 YLC mentorship luncheon with Ron Henley

Your career is a journey

During the SME Annual Conference, the Young Leaders Committee (YLC) invites an established member of the mining industry to speak at its mentorship luncheon.

HENLEY

Ron Henley, YLC's most recent mentor, is the president of GCC of America, a cement company based out of Chihuahua, Mexico. GCC consists of three cement plants, 84 ready mix plants, 22 distribution centers and one coal mine. Coal mined from the King II Mine is used internally for producing cement and also sold.

The topic of Henley's luncheon presentation was "Your Career is a Journey," in which he highlighted several points that are vital to professional development and a successful career.

Henley started as a mechanic in his uncle's John Deere dealership. Maintenance work gave him the fortitude that he relied on throughout his career. Later, he decided to pursue a college degree in finance and accounting. Upon graduating, he worked for KPMG as an auditor and later moved into mergers and acquisitions due diligence work. He moved to private industry, became a chief financial officer and gained experience in acquisitions and divestitures.

Henley then worked in operations where he gained experience in production, environment and improvement projects. He also worked in the planning and development of brownfield and greenfield expansions using a skill set in construction management. He explained the career moves as necessary to gain experience and credibility in several fields, which now contribute to his current role as president of GCC.

You just never know — the best laid plans

Some people start at the bottom and work their way to the top and others start in the middle and remain in the middle. It's not about where you start but where you end up. People who tend to make it to the top have made themselves flexible and open to new opportunities. Always perform your best, you never know who is watching.

Experience, not education, is what really counts

Henley explained that education is the base from which to grow. Learn through new opportunities that will expand your experience. Each new task is a chance to expand on your knowledge base and skill set. Studying what makes people tick will help you manage people effectively. The higher you get into management the less it becomes about technical skills and the more it becomes about people. He advises taking as many psychology and sociology classes as possible and using that information in dealing with people.

Make a difference

Make things happen; be a person of action. Successful people take challenges in stride. They become known as the go-to person. If you're asked to perform a task, do it. This will help increase your experience and confidence in your work. Always think bigger and get involved but remember to prioritize and keep things simple.

Do not be afraid to change lanes, even horses

Staying in one position for a long time isn't going to move you forward in your career. Moving sideways or even backward at times can end up getting you ahead in the long run. Henley warned that you cannot move forward or even sideways until there is someone to fill your position. There may be times that you hit a road block and cannot seem to break the barrier. At that point, it's time to move on to a different opportunity.

Focus on the job you have now

Don't get focused on the job you want or wished you had. Focus on the job at hand, the next job will take care of itself. "Work yourself out of a job; there is always room for talented people," Henley explained. Employees stay down into the details too much and are usually covered up in daily tasks. Learn to delegate. Delegation is the fine art of knowing just enough to ask the right questions but also knowing when you need to take a deep dive into the details. Treat your development like a bank. You have to make deposits before you make a withdrawal. Build rapport. It's amazing what it will do for you. Get people behind you to support your given situation. Get people on the same page as you. Study the U.S. presidents. Regardless of their politics, they had to have done something right to get there.

Reality and strategy

Henley discussed the differences between reality and strategy — what is and what we wish for. This includes understanding that surprises can be bad, but the truth will set you free. Understand the resources you have. Stretch them but don't over commit. Strategic thinking is what we wish to happen. There are certain steps that need to take place in order to implement a strategy.

1. Identify what is real. Be objective.
2. Ask why before how. What are you really trying to do?
3. Break down the issue.
4. Review your resources.
5. Develop a plan.
6. Enable the right people to achieve the plan's objectives.

The luncheon ended with a short question and answer period. ■

Michael Hitch gives guest lecture at ISM

by Ketan Mishra, ISM student chapter

SME's student chapter at the Indian School of Mines (ISM), Dhanbad, organized a guest lecture by Michael Hitch PG, PE, on April 14, 2015. Hitch is an associate professor of mining engineering at the Norman B. Keevil Institute of Mining Engineering, University of British Columbia. The lecture was attended by chapter members and the chapter's faculty advisor, A.K. Mishra.

Hitch presented a lecture on the topic of social license — a necessary part of mining. He discussed the problems faced in the initial stage of mining and the reaction of the local communities. The speaker further shared his views on the framework for responsible mining. ■

Michael Hitch (center right), Prof. A. K. Mishra (center left) and members of SME's ISM student chapter at the guest lecture on sustainable mining.

Fine Grind

(Continued from page 70)

focus on cost rather than sustainability, and wait for regulations. Others may be motivated to change but may not have sufficient understanding of the impact of particular chemicals on HSE.

Prudence requires the mineral industry to stay ahead of regulations by making wise choices and investments, thereby avoiding major penalties, closures or incurring substantial losses. Chemical suppliers should educate the industry on these HSE aspects. There is a great opportunity for all of us to tackle this big HSE challenge and to realize substantial gains for both industry and society, independent of boom-bust cycles. This would be both profitable and sustainable. ■

MEC

(Continued from page 69)

state's science teacher conference. Visit www.mineralseducationcoalition.org/SME-outreach-resources for free, downloadable handouts and discount bulk poster pricing for SME members, sections and student chapters. Contact Rachel Grimes, MEC Outreach Coordinator, at grimes@smenet.org or 303-948-4247 for more information.

Thank you to the 2015 NSTA area conference setup committees at each location. ■

SME members Joshua Leurquin (l) and Mike Garska (r) hand out educational materials at the 2014 NSTA area conference in Long Beach, CA.

Safety Share is the new Health & Safety Division newsletter

by Jürgen Brune, Division Secretary

Let me begin this column with a sad safety share. On Aug. 3, the U.S. Mine Safety and Health Administration (MSHA) reported the deaths of three miners in the metal and nonmetal industries who suffered fatal injuries in three separate accidents pages. According to an MSHA statement published Aug. 5, 2015, a loader operator at a North Dakota sand and gravel operation was covered up in a stockpile failure; a Nevada miner was struck by mobile equipment in a gold mine and a Virginia gravel plant operator was buried when a silo collapsed. MSHA will, of course, investigate each of these accidents, and we must await the results to draw further conclusions.

To the families, friends and loved ones of these victims, on behalf of SME and its members, I want to express my sincere condolences. You are in our thoughts and prayers at this difficult time.

The SME Health & Safety Division was formally established by the SME Board of Directors on Feb. 15, 2015. Establishing a division focused on health and safety in the mining and minerals industries recognizes the importance of protecting our employees from injury and illness, and it also recognizes the fact that a large number of SME members spend the majority of their work on safety and/or health. As the leading professional society in the mining, minerals and underground construction, SME strongly supports and promotes safety and health in our industry.

As you renew your memberships this fall, I encourage you to consider marking your professional interest and affiliation with the Health & Safety Division, if this reflects the majority of work you do.

Division strength measurement

One indicator SME uses to measure division strength is the number of members who belong. With the establishment of the Health & Safety Division, other divisions voiced concerns that the new division might take away their members. In an attempt to resolve this issue, SME currently permits choosing up to two divisions of professional interest. Members are asked to make first and second selections, with the first selection counting as the primary division. My personal problem — selecting health and safety second does not sit well with me.

This dilemma stems from the traditional structure of SME. Membership has been organized in divisions related to professional interest — coal and energy, mining and exploration, industrial minerals and aggregates, mineral and metallurgical processing, and underground construction and tunneling. This made it rather simple for members to belong to the group that best represented their professional interests. By the way, I don't like it that we call them divisions, because this reminds me of silos that divide our membership rather than uniting it.

With the creation of the Environmental Division in 2005, SME created a new organizational structure that cut across all of the traditional divisions. Members may work in underground construction or in mineral processing, while they also have a strong professional interest in environmental issues. Thus, they have a vested interest in belonging to both groups.

The new Health & Safety Division cuts across the professional segments the same way. I have worked in the coal industry for the majority of my career, but I have spent the last 20 years increasingly involved in safety and health. My professional interests clearly lie both in health and safety and in coal and energy. I want to mark both my interests with equal weight, and I want to continue my work for the Society by serving on committees in both divisions. SME is morphing from a "silo" to a "matrix" structure, and that is a good move. So, here is my suggestion. SME, count dual division interests equally for both divisions, and let's move to valuing each division by the technical programming and professional contributions by its members, not by the mere number of those who ticked a box.

At the 2016 Annual Conference and Expo in Phoenix, AZ, Feb. 21-24, the Health & Safety Division will offer seven technical sessions with — at last count — 47 presentations. Please mark your calendars, and I look forward to seeing you in Phoenix. ■

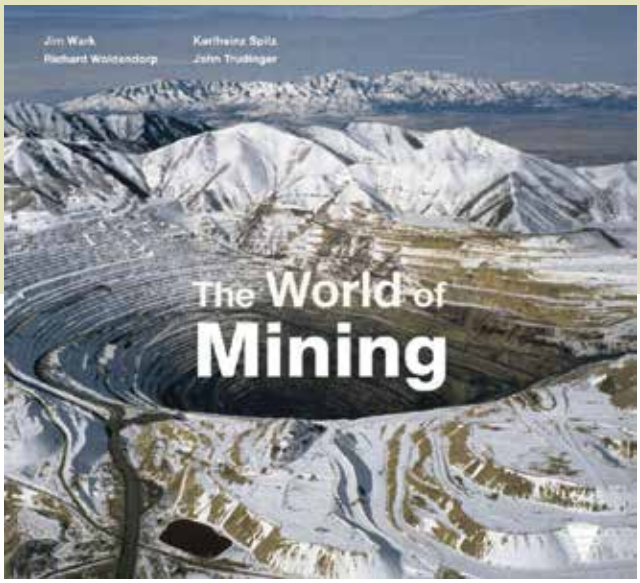
Safety Share **serves as a forum for the presentation and discussion of facts, ideas and opinions pertaining to the interests and technology of the Health & Safety Division. Accordingly, all material published herein is signed and reflects the individual view of the authors. It is not an official position of SME or the division. Comments by readers will be referred to that division for response. The division chair in 2015 is Eric Lutz.**

Personal News

(Continued from page 68)

GORDON BABCOCK (SME) was appointed Sierra Metals' new chief operating officer as of July 2015. He has more than 34 years of experience in mine production management, project development, engineering, exploration and mine consulting in precious metals, base metals and aggregates. He was previously a mining operations executive with Jaguar Mining and Breakwater Resources. Sierra Metals has also appointed **MATTHEW WUNDER** as its vice president of exploration, replacing **THOMAS ROBYN** who retired. Wunder is a professional geologist with more than 25 years of experience in mineral exploration. He previously worked for Rubicon Minerals, Noranda and Antamina. ■

The World of Mining



In this truly unique celebration of mining, breathtaking aerial photographs by award-winning photographers Jim Wark and Richard Woldendorp accompany ground-level pictures of mines, mine-side oddities, and mine communities. Informed but breezy narratives by mining experts John Trudinger and Karlheinz Spitz identify and explain the images.

The World of Mining shows that mining and associated activities can be impressive, attractive, and even spectacular. The book illustrates most if not all aspects of mining and mineral processing, in all its varieties, and from different environments throughout the world. It illustrates the colorful history of mining and its importance to the development of civilization as we know it. It depicts the wide range of activities in modern mining, from exploration to mine closure, as well as traditional mining by skilled practitioners, using methods adapted to local conditions.

The World of Mining

By Richard Woldendorp, Jim Wark, Karlheinz Spitz, and John Trudinger

2011, 292 pages, 5 lbs
Published by Taylor & Francis
Book Order No. 9105
$80 Member / $80 Student Member / $95 Nonmember/List

Contents

Upcoming SME Events

Environmental Considerations in Energy Production
Sept. 20-23, 2015
Omni William Penn Hotel
Pittsburgh, PA, USA

Review Course for Professional Engineers Exam
Sept. 26-30, 2015
Hilton St. Louis Airport Hotel
St. Louis, MO, USA

SME Florida and Dreyer Conference
Oct. 7-8, 2015
The Lakeland Center
Lakeland, FL, USA

For additional information, contact: Meetings Dept., SME
Phone 800-763-3132 • 303-948-4200 • Fax 303-979-3461 • email sme@smenet.org • www.smenet.org

Visit www.miningengineeringmagazine.com for more industry events or to list your event online.

September 2015

1-4 • AIMEX 2015
Sydney Showground, Sydney, NSW, Australia
Phone: 61-2-9211-7544
email: aimex@reedexhibitions.com.au
http://www.aimex.com.au

9-11 • 12th International Conference on Mining Maintenance
Grand Hyatt Hotel, Santiago, Chile
Phone: 56-2-2652-1500
email: gecamin@gecamin.com
https://gecamin.com/mapla.mantemin/english

14-16 • International Heap Leach Solutions 2015
Peppermill Resort Hotel, Reno, NV, USA
Phone: 604-683-2037
email: heapleach@infomine.com
www.heapleachsolutions.com

16-18 • Precious Metals Summit 2015
Park Hyatt Beaver Creek, Beaver Creek, CO, USA
Phone: 303-861-2211
email: info@precioussummit.com
www.precioussummit.com

21-25 • Perumin Mining Convention 2015
Universidad Nacional de San Agustin de Arequipa, Arequipa, Peru
Phone: 51-1-313-4160-331
www.convencionminera.com/perumin32/en/index.php

23-25 • Mining Agreements: Contracting for Goods and Services
Vancouver Marriott, Vancouver, BC, Canada
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October 2015

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www.titanium.org

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Cornelia Diamond Golf Resort, Antalya, Turkey
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www.flogen.org/sips2015

5-9 • Sampling Theory, Practices and their Economic Impact
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http://csmspace.com/events/sampling/registration.php

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21-23 • Procemin 2015 - 11th International Mineral Processing Conference
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27-29 • OTC Brasil 2015
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November 2015

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www.aiche.org/cmtc2015 ■

CeraLine from Blasch Ceramics exhibits exceptional abrasion resistance

Blasch Precision Ceramics has announced its new abrasion resistant product line including ceramic-lined elbows, pipe and spool linings. CeraLine is specifically designed for the harsh environments of mining, power generation and other heavy industrial processing industries,

The CeraLine family of products exhibits exceptional wear and abrasion resistance that results in extended product life. The unique casting process facilitates the manufacture of smooth bore, one-piece, abrasion-resistant elbow linings. Pipe diameters from 1.27 cm (0.5 in.) to several feet can be lined with Blasch pre-cast tight tolerance shapes available with engineered joints and a smooth bore that eliminates premature wear and interrupted flow.

CeraLine is suited for the severe environments of the processing industry.

Available in a variety of premium refractory materials and complete turnkey units with steel pipe and flanges, the systems are individually engineered to suit specific applications and offer a drop-in replacement to existing piping.

www.blaschceramics.com

Valves with a freeze plug are available from Freeze-Tolerant Ball Valves

Freeze-Tolerant Ball Valves offers a new type of valve that has a freeze plug forged into the side wall of the valve to act as a sacrificial disk. During a freezing situation, the body of the valve is protected from the expanding ice, and the freeze plug relieves the pressure — or one can simply remove the plug for winter to ensure complete draining.

The main body of the freeze-tolerant valve has been increased to double that of a conventional valve thickness. This allows the freeze plug to be at a safe thickness, so it will meet the same operating pressure ratings of the valve. The freeze plugs are specially designed to withstand a burst pressure of 10,342 kPa (1,500 psi), and yet they will rupture in the event of ice formation within the valve.

The new type of valve is ideal for the mining, oil and gas and fracking industries that operate 24 hours a day, seven days a week and cannot afford costly down time for repairs. An operator can change out a freeze plug in five minutes with zero downtime because the piping system stays intact and online.

www.freezetolerantballvalve.com

Systems Group offers water cooling equipment for metals and materials

The Systems Group strives to provide the safest and most responsive products to cool and maintain its customers' workplaces. One of its divisions, Systems Spray-Cooled, manufactures a patented line of nonpressurized, nonevaporative water-cooling equipment for the metal and minerals industries. It is a safer, greener alternative to conventional cooling equipment used in electric arc furnace melt shops and other extreme heat-load applications.

Because spray-cooled equipment operates at atmospheric pressure, the cooling water is not pumped across the area to be cooled. Therefore, the potential for high-pressure, high-volume water leaks is eliminated. Positive extraction of the spent cooling water further reduces the amount of water present within the equipment.

By design, the Systems equipment provides a means for accessing the hot face from the wet side of the plate. This provides much safer inspection and repair from above and eliminates the need to access the hot face from the hot side.

www.tsg.bz

Hyundai introduces the HL900 series wheel loaders

Hyundai Construction Equipment Americas has launched its new HL900 series line of Tier 4 final-compliant wheel loaders, available throughout the United States and Canada. The new wheel loaders have been proven to deliver as much as five percent greater productivity and 10 percent lower fuel consumption than the previous 9A series loaders.

The first models available for sale include the HL940, HL955, HL960, HL970 and HL980. Additional wheel loader models, including the HL935, and special model configurations, such as the Tool Master and Extended Reach models, will be available in the fourth quarter of 2015.

The cab on the Hyundai HL900 series wheel loaders is up to 10 percent larger than previous models and has been reconfigured for additional floor space and improved visibility. The cab is equipped with features that enhance operator productivity, including a larger 17.8-cm (7-in.) interactive touch-screen monitor, optional finger-tip controls, fully adjustable and heated air-ride seat, and centralized control switches for added convenience. The enhanced climate control system, which features high-capacity filter and additional airflow vents for optimum cooling and heating efficiency, is conveniently positioned for easy service access on the right side of the cab.

In-cab sound levels were reduced by 3 dB, making this one of the quietest cabs in the industry.

www.hceamericas.com

Dust filter valves improve drill rig efficiency

Fast-acting dust filter valves from IMI Buschjost help prevent drill-string jams and the shutdown of surface top-hammer drills by improving the performance of dust collection systems. The jet-pulse or reverse-pulse dust collectors rely on timed blasts of compressed air to shake the caked dust off the filter bags into the collector.

IMI Buschjost dust filter valves open in milliseconds, so air pressure reaches a set point quickly to deliver intense bursts. Rapid, intense airbursts are the most effective way to clean the filter bags. They also reduce demand for compressed air, thereby decreasing energy consumption.

The dust filter valves are constructed of high-grade materials and a frost-proof solenoid, giving them a broad temperature range from -40°C to 140° C (-40°F to 284°F). This means the same valve can be specified for equipment operating anywhere in the world.

In addition, when used properly, the valves are explosion-proof up to hazardous area 1/21 and are available in high corrosion-resistant models. The valve's twist-on design allows replacement without tools.

www.norgren.com/us/info/83/blasthole_drilling

MTG launches a new LHD lip system

MTG has launched a complete bucket protection system for loaders in underground mines. The load-haul-dump (LHD) lip system has been tested with excellent results in Canadian and Portuguese mines. The welded system comes with an ultra-slim design that optimizes bucket penetration and reliability, increasing machine productivity and operational time. The shroud is capable of reducing fuel and pneumatic consumption, compared to mechanical protectors, thus providing a great competitive advantage for the user.

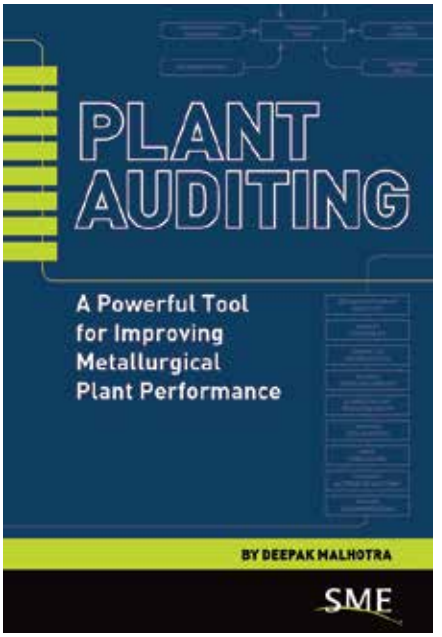
The welded-lip shrouds are designed to maximize bucket penetration for loaders in underground mines.

The lip system is produced with a new steel alloy, MET40LH, which was developed to maximize the hardness and protection of the bucket without losing the weldability of steel. Other advantages include the shroud's self-sharpening design as well as installation versatility in any bucket width. Currently, MTG offers the lip system for loader buckets with a thickness of 38 mm (1.5 in.). A newer version with more wear material at the lower part for more abrasive applications is already planned. ■

www.mtg.es/en/index.php

Plant Auditing

2015, edited by Deepak Malhotra, published by SME, 12999 E. Adam Aircraft Cir., Englewood, CO 80112, USA, www.smenet.org/store, email books@smenet.org, phone 303-948-4225, 800-763-3132, 148 pp., soft cover, ISBN 978-0-87335-412-7, $69 member, $49 student member, $99 list. Available as an eBook from www.smenet.org/books.



The word audit brings discomfort to many mine managers and owners. Images of government officials poring over every decimal point, looking for "gotchas" with serious consequences, naturally rise to the surface.

This book shows the reader how to turn the audit into something positive, desirable and profitable. Hiring the right audit team and putting its recommendations into practice can lower costs, increase revenues and boost profits. In some cases, you can add millions of dollars directly to the bottom line.

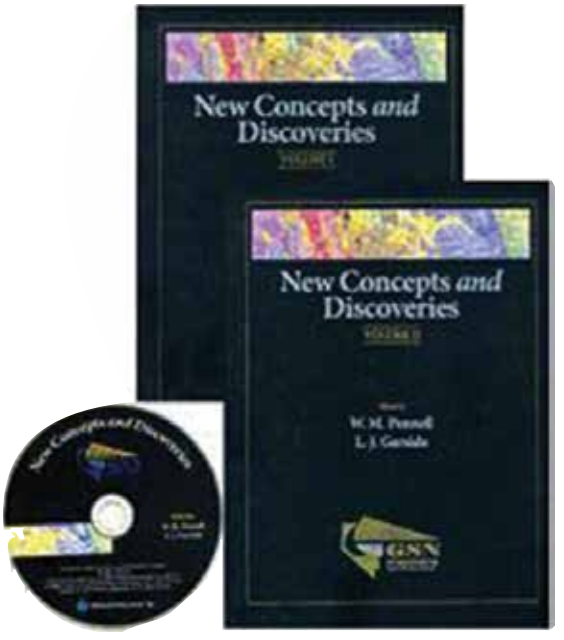
Plant Auditing is the first book ever written to show how to get maximum benefit out of an audit. This comprehensive guide is easy to follow with numerous charts and checklists. It details the complexities of setting up the right kind of audit, the type that will provide actionable steps to profitable outcomes. Also included are 20 case studies illustrating real-life problems typically encountered at plants that can be resolved through the audit procedures described in the book.

Among many other things, the book shows how to establish the scope of general audits and those designed to enhance performance of specific processes; to follow a template for successful audition; to set priorities based on multiple factors; to understand and overcome resistance points based on cultural or personality differences; to make sure everything important is addressed during an audit and to turn the audit findings into action steps that cut costs and add revenue.

New Concepts and Discoveries Geological Society of Nevada 2015 Symposium

2015, edited by William M. Pennell and Larry J. Garside, published by DEStech Publications, 439 N. Duke St., Lancaster, PA, 17602, USA, 877-500-4337, www.destechpub.com /online-bookstore/, 1,388 pp., hardcover plus CD, ISBN 978-1-60595-226-0, $340.

Produced under the auspices of the Geological Society of Nevada and published every five years, this two-volume book of peer-reviewed papers focuses on the geological analysis of ore-rich deposits in the western United States, especially ones containing gold and other high-value elements. Hundreds of stratigraphic, lithographic, remote-sensing and core sample examples are presented, particularly of areas likely to host Carlin-type gold deposits. The two volumes contain a wealth of data on specifically named mines, as well as technical information on high-potential areas for exploration. The book is profusely illustrated with full-color maps, photographs and charts for geology and mining engineering.



A searchable CD accompanies the book and includes the full text of papers from the printed book, as well as abstracts and information from poster sessions not found in the printed book. Chapters in the text are fully refereed versions of presentations originally delivered at a symposium supported by the Geological Society of Nevada, along with the U.S. Geological Survey, Society of Economic Geologists and the Nevada Bureau of Mines.

Some of the highlights of the book include:

- Scientific analyses of the geology, metallogeny and mineralization of gold, silver and other elements in the western US.
- Technical details on working mines, exploration results, new deposits.
- Presentations produced with the U.S. Geological Survey and the Society of Economic Geologists. ■

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Index of Display Advertisers

Mining Engineering September 2015

Barrick Gold	Inside Front Cover
Camfil Air Pollution Control	3
DOWL	12
Eriez	29
Flanders Electric	35
Geoprobe	36
Jennmar Corp	5
Liebherr Mining Equipment	20-21
Miner Elastomer Products	33
MTU	39
Naylor Pipe Company	31
Nelson Irrigation	32
Netzsch	28
Ore-Max	37
Phoenix Extreme Conveyor Belt Systems	14-15
Sandvik Mining & Construction	22-23
SRK Consulting	33
Turnkey Processing Solutions	26-27
Veolia Water Technologies	24-25
Weir Minerals	11, Outside Back Cover

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Mineral exploration on public land

Steve Kral,
Editor

Briefing paper discusses issue

SME's Government and Public Affairs Committee has produced a number of technical briefings in recent years that are designed to educate policymakers and the public about the importance of mining. The briefings are factual documents not designed for lobbying. They are researched, written and reviewed by mining professionals.

One briefing is titled "Access to Public Lands for Mineral Exploration." This is an issue faced by the domestic mining industry for decades, with no political answer on the horizon. Here is what the briefing says and SME's take on the issue.

The United States depends on minerals for economic growth and development, and for national security and defense. Public lands are an important, long-term source of essential minerals.

Access to public lands for mineral exploration and development has become more difficult as large tracts of land have been designated for other uses. Mineral-bearing areas on public lands are routinely withdrawn or restricted from development before comprehensive resource inventories and economic assessments have been made.

The United States is a mineral-rich nation. The nation has reserves of more minerals and metals commodity minerals (78) than any other country. The current value of select mineral resources in the U.S. is estimated to be $6.2 trillion.

The U.S. is a significant consumer of minerals, domestically produced and imported. According to the U.S. Geological Survey, the value added to the nation's gross domestic product (GDP) by major industries that consume processed mineral materials in the United States is $2.3 trillion, which is 16 percent of GDP of $14.7 trillion.

Minerals found on public lands include locatable minerals — including copper, iron, zinc, lead, rare earths and other strategic minerals, precious metal ores, and certain classes of industrial minerals; leasable minerals – including oil, gas, coal, oil shale, sodium, potash, phosphate, and all minerals within acquired lands; saleable minerals – including common varieties of construction materials and aggregates

The U.S. Bureau of Land Management (BLM) administers mineral resources on 700 million acres of public lands, or about one-third of the land mass of the entire country, most of it in 12 western states. Of that 700 million acres, 167 million have been withdrawn, and another 182 million acres are restricted from future development. The BLM manages both surface and mineral rights of its public lands domain. The agency manages its surface and the mineral rights while other agencies manage only their surface.

Public lands account for as much as 86 percent of the land area in certain western states. These same states account for 75 percent of the nation's metals production. As such, access to federal lands for mineral exploration and development is critical to maintain a strong domestic mining industry.

The environmental impacts of mining on federal lands are addressed by a range of federal, state and local regulations. These create a rigorous set of mining and reclamation standards for the domestic exploration and mining industry that are emulated worldwide.

Access to public lands provides the United States the opportunity to find and produce essential minerals, to significantly offset foreign mineral dependence, to decrease a growing trade deficit, to create skilled jobs and to help solidify the nation's economic security.

Public lands should remain open and available for mineral exploration and development unless Congressional withdrawals or administrative actions are clearly justified in the national interest. A thorough geological and economic assessment should be made before any land is withdrawn.

Given the lack of current and recurring geological assessment of many withdrawn areas, it is uncertain what minerals, and in what quantity and quality, occur on such lands. Periodic reassessments should be made of these lands.

Mineral exploration and development usually requires a relatively small footprint and is a temporary land use that can occur concurrently or sequentially with other public resource uses.

When mineral development occurs it must be held to the highest technical and regulatory standards in order to limit the environmental impact. ■

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COVER STORY

In this issue — The Deep Rock Tunnel Connector project is being built to address combined sewer overflows into the White River in Indianapolis, IN, page 36. The Southern Nevada Water Authority-contracted for a new deep-water intake located at Lake Mead, page 43. The UCA of SME is hosting the ITA's World Tunnel Congress, page 29. Photo courtesy of Robbins.

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CONTENTS

FEATURE ARTICLES

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CHAIRMAN'S COLUMN

WTC 2016 is around the corner

First and foremost, I want to thank the entire UCA of SME Executive Committee for it's confidence in me and for electing me as chair. My personal thanks to past chairs, such as Bill Edgerton, Jeff Peterson, Dave Klug and others, for their excellent leadership over the years. Also, a big thank you to Dave Kanagy and the entire UCA of SME staff for all they do to help us serve the underground community of contractors, engineers, suppliers, owners and educators.

The 2015 Rapid Excavation and Tunneling Conference (RETC) was held in New Orleans, LA in early June, and it was a tremendous success, with 1,250 attendees and 157 exhibitors. The 113 papers presented were well received, and many attendees had positive comments on the innovative procedures being implemented to achieve successful projects. A big thank you goes to the conference chair and working groups who brought everything together for a spectacular conference. As always, the lessons learned from the event will be used to improve future RETC, North American Tunneling, Cutting Edge and George A. Fox conferences.

Our underground industry is very busy these days, advancing many types of infrastructure facilities including roadway tunnels, rail tunnels, water distribution tunnels, utility tunnels and CSO tunnels, as well as rehabilitating many aging facilities. As our work continues to grow, so must our personnel and their expertise. It is through our organization that new and innovative techniques must be shared for the benefit of our clients and the ultimate users of the facilities we bring to fruition. Sharing techniques via our conferences and publications is vital so that we, as an entire industry, can grow in our ability to assist our clients.

At the last UCA Executive Committee meeting following the RETC, a new scholarship committee led by Mike Roach was created. I want to encourage all UCA members to reach out to their staffs, friends, neighbors and students to encourage scholarship candidates to submit applications for review and consideration by the committee later this year. An application can be found at http://uca.smenet.org/scholarships.

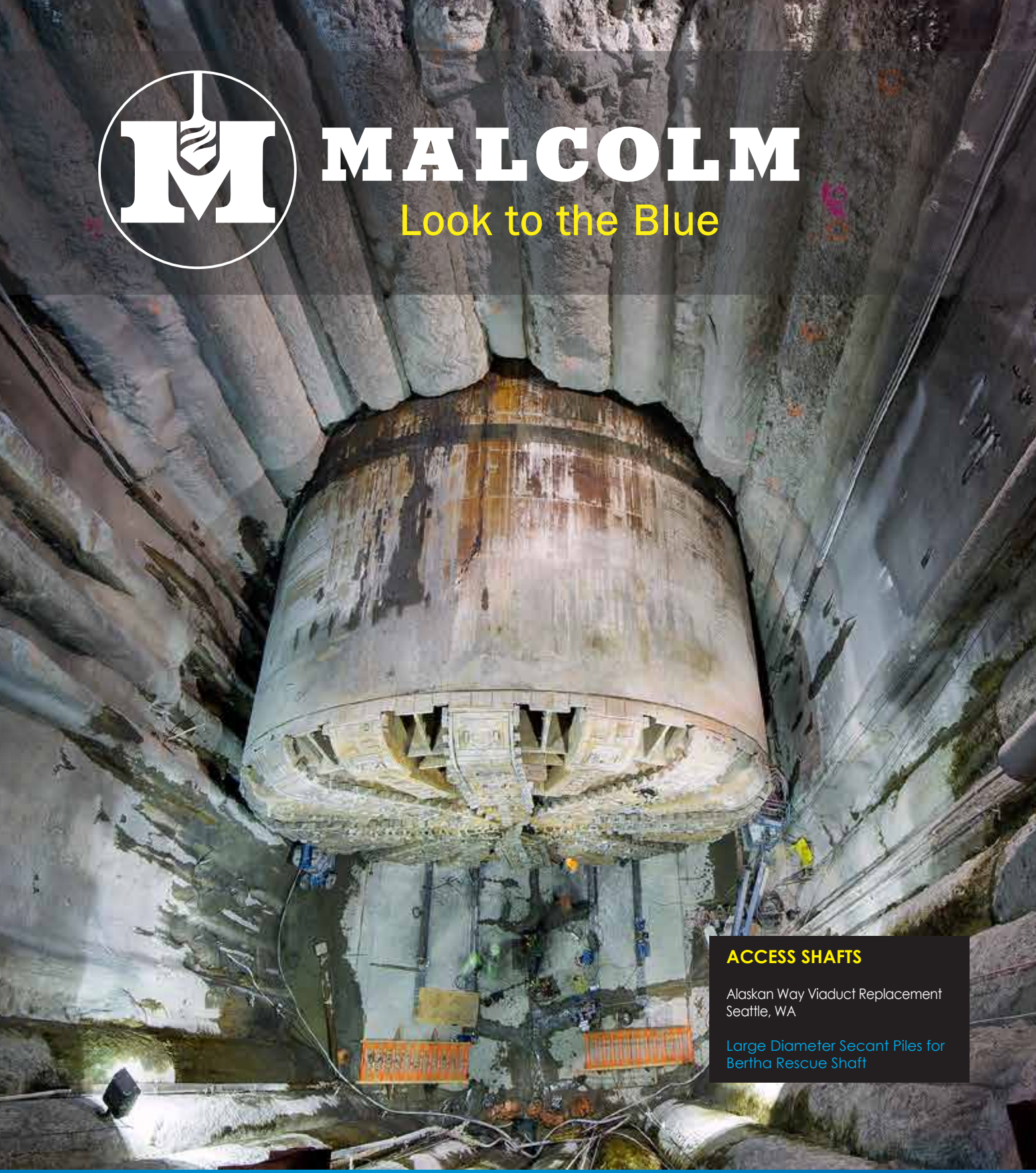
The Young Tunnelers members group and the Women in Tunneling group are gaining momentum. Our organization fully supports them and encourages greater participation. We have already committed funding and other support to both groups, and the executive committee is asking all members to assist them whenever possible as we grow our Association's diversity.

Nearly four dozen UCA members and staff attended WTC 2015 in Croatia. The sessions and networking opportunities were tremendous and many observations were made and recorded. We are very fortunate that WTC 2016 will be combined with our NAT 2016 to be held in San Francisco, CA on April 22 to 27, 2016. Mark your calendars and find out more at www.wtc2016.us/.

Many of our organization's members are busy finalizing arrangements for this world-class event. The 2016 conference chairs are busy making necessary preparations, appointing manuscript reviewers, arranging the spouse/guest tours and events and preparing a coffee table book for distribution to all attendees. This event will be an opportunity for the United States to shine and to raise the bar for all future World Tunneling Congresses.

Registration and hotel booking is now open, along with the opportunity to select vendor booth space, which is selling quickly. Please take steps to reserve your space soon. I'll see you there. ■

Artie Silber,
UCA of SME Chair



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US transportation secretary opens discussion about Gateway Project

Following consecutive days of train delays that locked up parts of the New Jersey Transit systems in July, U.S. Transportation Secretary Anthony Foxx reached out to the governors of New York and New Jersey urging them to meet with him to map out a strategy to advance on the long-stalled plans for new Hudson River rail tunnels.

The current tunnels used by New Jersey Transit and Amtrak to traverse the Hudson are 100 years old and many feel they need to be replaced.

The New York Times reported that Foxx asked Gov. Chris Christie of New Jersey and Gov. Andrew M. Cuomo of New York to meet to discuss their states' roles in a proposal, known as the Gateway Project, to build new rail tunnels.

"The condition of the trans-Hudson tunnels is a major threat to the region and to our nation's transportation system," Foxx wrote. "I write to urge immediate action and to lend my personal engagement to get the Gateway tunnel project on the path to completion as soon as possible."

In 2010, the project to build new tunnels under the river known as Access to the Region's Core (ARC) was shelved by Christie who cited concerns that New Jersey would be held responsible for cost overruns. A spokesman for Christie, Brian Murray, told *The New York Times* that the governor was happy to meet with Foxx and Cuomo.

"He has always been and remains committed to expanding cross-Hudson capacity, so long as it is equitably funded by everyone who benefits regionally and not disproportionately on New Jersey taxpayers as the ARC project was," Murray said in a statement.

In June, transportation officials from the region supported the project in a letter to Foxx, asking for the Gateway Project to be considered for a federal program that helps provide financing strategies for infrastructure projects.

Amtrak officials say the current tunnels need to be closed for repairs because of damage from Hurricane Sandy, but that closing one of the two tunnels would substantially reduce the number of trains that could travel between New York and New Jersey, especially during morning and evening rush hours.

On a trip to New York City, Foxx said the Gateway plan was one of the most important rail projects in the country, and he called the lack of action to repair the tunnels "almost criminal." Since 2010, Christie, a Republican who is running for president, has not put any political muscle behind restarting the projects, which would cost billions of dollars when the state already faces a growing backlog of urgent but unfunded transportation projects.

In his letter, Foxx said that the Obama administration was willing to explore federal financial assistance for the project. The Federal Railroad Administration and Amtrak have discussed financing tools to get the project started, he said, but they needed support from the states.

"Neither Amtrak nor your individual states, acting alone, can replace these tunnels," he wrote. "It will take all of us working together."

At an event in Manhattan where Cuomo, a Democrat, and Vice President Joseph R. Biden Jr. announced an overhaul of La Guardia Airport, Biden, who as a senator was a regular on Amtrak trains, briefly touched on the problems of the Hudson River tunnels and the need for collective action.

"I'd ask Governor Christie to come back and talk about it," Biden said.

In a letter to Foxx, the officials from New Jersey and New York said the Gateway Project was an "urgent necessity." The June 26 letter was signed by an array of transportation officials: Amtrak's president, Joseph H. Boardman; New Jersey Transit's chairman, Jamie Fox; New York's then-transportation commissioner, Joan McDonald; the Metropolitan Transportation Authority's chairman, Thomas F. Prendergast; New York City's transportation commissioner, Polly Trottenberg; the Port Authority of New York and New Jersey's executive director, Patrick J. Foye; and New Jersey Transit's executive director, Veronique Hakim.

"We stand ready to participate in the broad and equitable collaborative effort that will be needed among all sectors of government and private industry to improve the rail infrastructure of the Northeast Corridor as indicated," the letter said.■

"The condition of the trans-Hudson tunnels is a major threat to the region and to our nation's transportation system. I write to urge immediate action and to lend my personal engagement to get the Gateway tunnel project on the path to completion as soon as possible."

U.S Transportation Secretary Anthony Foxx, in a letter to the governors of New York and New Jersey

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Seattle Tunnel Partners announce new schedule for Bertha

As the tunnel boring machine (TBM) gets closer to being repaired, Seattle Tunnel Partners released an updated schedule for the SR-99 project that puts the completion of the tunnel in the spring of 2018, 27 months behind the original schedule.

Seattle Pi reported that the TBM, called Bertha, was expected to resume digging the nearly 3.2-km (2-mile) tunnel beneath Seattle, WA on Nov. 23, about 24 months after it came to a stop 300 m (1,000 ft) into the dig.

While project planners were able to set a new schedule, they have not been able to say for sure how much over its $3.1 billion budget the project might go, and it's unclear how those costs will be divvied up by the contractor.

"That's all going to be sorted out within the contract requirements, so that's something that occurs sometime in the future," said Chris Dixon, project manager for Seattle Tunnel Partners, the contractor digging the tunnel. "The focus now is to get the TBM repaired, up and running so we can complete the tunnel drive."

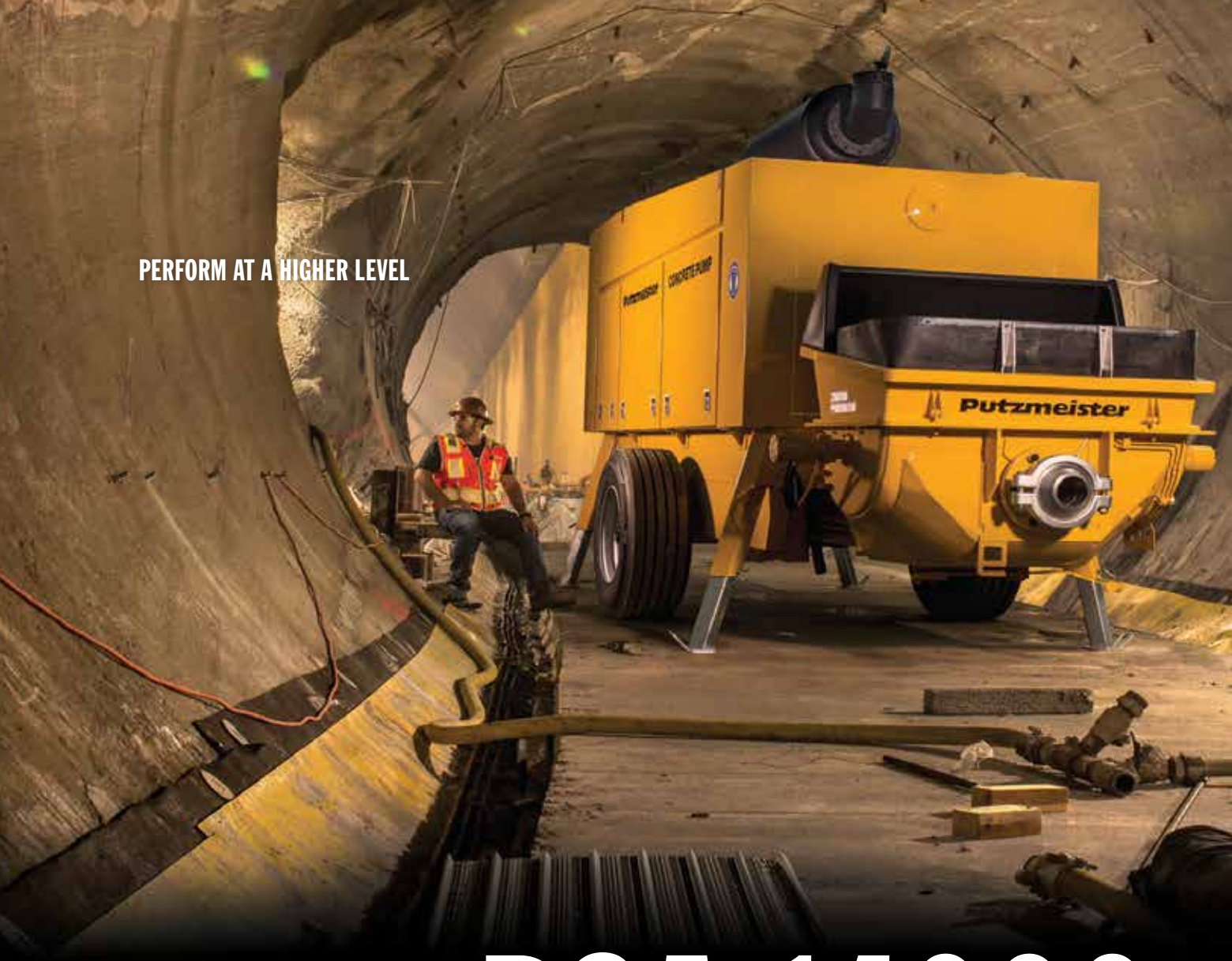
Washington Department of Transportation officials said the state cannot verify the contractor's schedule, but they have confidence in the new schedule and will keep a close eye on progress to make sure things are going forward as promised.

The details of the schedule are the responsibility of Seattle Tunnel Partners, said Todd Trepanier, the state DOT's Alaskan Way Viaduct Replacement Program administrator.

"We've asked them to give us a tunnel with a roadway in it," Trepanier said. "They've made the decision on how they're going to do that."

Changes to the schedule — and any costs that go with that — fall on Seattle Tunnel Partners, not

(Continued on page 14)



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DC Water's first TBM completes 4.5-mile tunnel for cleaner Anacostia River

DC Water's 7.2-km (4.5-mile) long tunnel was completed with the breakthrough on July 23 of the tunnel boring machine (TBM) called Lady Bird.

The tunnel will be used to help improve the water quality in the Anacostia River. Lady Bird completed her dig and her cutterhead was extracted from a 30-m- (100-ft-) deep shaft near DC Water's Main Pumping Station in Southeast Washington, DC.

Tunneling began in July 2013, from a starting point at the Blue Plains Advanced Wastewater Treatment Plant. Lady Bird tunneled along the Potomac River northward to Poplar Point and then crossed under the Anacostia River and continued west, finishing at a deep shaft along Tingey Street, SE. To prepare for her arrival, this shaft was filled with flowable fill concrete and water, to protect against changes in pressure as Lady Bird mined through the shaft wall.

"This is a terrific milestone for DC Water's Clean Rivers Project," said DC Water chief executive officer and general manager George S. Hawkins. "We are fortunate that the tunneling went so smoothly, finishing on time and on budget, and I applaud our DC Water staff as well as Traylor Skanska Jay Dee and everyone else who took part in this successful dig."

DC Water's Clean Rivers Project will incorporate two methods to keep combined sewage and stormwater from overflowing into waterways, during heavy rains in the parts of the city with a combined sewer system. The first is to build underground tunnels that will hold combined sewage and stormwater until rain subsides, then convey it for treatment at Blue Plains. The second is to create green infrastructure to capture and

(Continued on page 17)

Tunneling efforts on Crossrail Project complete

It was a monumental effort that included eight tunnel boring machines (TBM) and took nearly three years for the 42-km (26-mile) tunneling portion of the Crossrails Project to be completed in June.

The British Prime Minister David Cameron and Mayor of London, Boris Johnson, celebrated the completion of Crossrail's tunnels by going 40 m (131 ft) below the capital to thank the men and women who are constructing the new £14.8 billion east-west railway.

"Crossrail is an incredible feat of engineering that will help to improve the lives of working people in London and beyond. The project is a vital part of our long-term plan to build a more resilient economy by helping businesses to grow, compete and create jobs right along the supply chain," said Cameron.

Crossrail tunneling began in the summer of 2012 and ended at Farringdon with the break through of tunneling machine Victoria, one of the eight 1-kt (1,000-st) TBMs that bored the new 6.2-m (20-ft) diameter rail tunnels under London.

Construction is also advancing on the 10 new Crossrail stations and on works above ground west of Paddington and east of Stratford. More than 10,000 people are currently working on Crossrail, including more than 450 apprentices.

With the arrival of Crossrail in 2018, Farringdon will become one of the UK's busiest rail hubs with direct connections to London Underground and upgraded and expanded Thameslink services. This brand new interchange will transform the way passengers travel through London and the South East, providing more capacity and direct connections to three of London's five airports and international rail services at St Pancras.

Crossrail will add 10 percent capacity to London's rail network. It will serve 40 stations, connecting Reading and Heathrow in the west with Shenfield and Abbey Wood in the east. Transport for London (TfL) run Crossrail services through central London will commence in December

(Continued on page 18)

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Bechtel-led team begins work on $10 billion Riyadh Metro Project

Bechtel will lead a global consortium on the construction of the Riyadh Metro project in Saudi Arabia, one of the largest underground rail systems in the world.

Bechtel has already begun tunneling on Line 1 of the Riyadh Metro, marking an important milestone in the construction of this landmark project, *Reuters* reported.

The Bechtel-led consortium, which includes Saudi company Almabani General Contractors, Middle East-based Consolidated Contractors Co., and Germany's Siemens AG, is responsible for the $10-billion contract for the design, construction, train cars, signaling, electrification and integration of Lines 1 and 2 — two of the most challenging lines on the Riyadh Metro Project. The work includes 39 stations, two of which are key interchange stations: Olaya Station, situated in the center of Riyadh at the intersection of Lines 1 and 2, and King Abdullah Financial District Station, located slightly to the north on Line 1.

"The metro, set to be the cornerstone of Riyadh's new public transport network, will revolutionize how people move around the city," said Amjad Bangash, Bechtel's director on the project. "Sending our team's first tunnel boring machine on its underground voyage is a significant step for all."

Bangash said the tunneling work beneath the streets of the Saudi capital will prove challenging. "Getting early agreement on the alignment in the heart of the city was crucial to advance the detailed design work needed to start tunneling. We appreciate the efforts that our client, Arriyadh Development Authority (ADA), and many other stakeholders undertook in helping us achieve this."

The first tunnel boring machine, Mneefah, named after the horse of Saudi Arabia's founder King, will steadily ramp up to its planned average tunneling rate of about 100 m/week (325 ft/week) and is expected to complete its journey by mid-2016. In total, seven tunnel boring machines will be deployed by the Bechtel-led team to dig and construct

(Continued on page 20)

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Seattle: TBM expected to be running in November

(Continued from page 06)

taxpayers, Trepanier said.

Dixon said it's still unclear exactly what caused the breakdown of Bertha, but he has confidence that, with repairs and upgrades meant to make the machine work better, it will complete the tunnel.

"We're doing something here that's unprecedented," he said. "We're tunneling with the world's largest tunnel boring machine, it's essentially a prototype, there's never been one manufactured like it before. We think it's better to take more time and do it right."

We're doing something here that's unprecedented. We're tunneling with the world's largest tunnel boring machine, it's essentially a prototype, there's never been one manufactured like it before. We think it's better to take more time and do it right."

Chris Dixon, project manager, Seattle Tunnel Partners

Bertha will resume digging almost two years to the day after getting stuck and breaking down Dec. 6, 2013.

Despite that delay, work has continued on both the south and north ends of the project and workers have completed 128 m (432 ft) of what will be the southbound upper deck in the section of tunnel behind Bertha.

At the south end of the tunnel, about 640 m (2,100 ft) of cut-and-cover — essentially the entrance to the tunnel — is already dug, with part of it covered.

Entering the actual tunnel, emergency and utility access tunnels line one side of the area that will eventually be the northbound lower deck, and water drips in from underground aquifers that surround both the entrance and the tunnel itself. Later, the whole thing will be sealed up.

Extensive repairs and upgrades should be completed in the fall, and then the cutting head will be lowered back into the pit and reinstalled before two months of testing takes place, Dixon said. ■

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Construction begins on Hawaii's longest tunnel

In the spring of 2015, by the idyllic shores of Oahu, HI, a Robbins 3.96-m (13-ft) diameter main beam tunnel boring machine (TBM) began its long journey. The TBM started its excavation on a 4.6-km (2.8-mile) drive for a new sewer tunnel in Kaneohe, Honolulu, HI. The machine, nicknamed Pohakulani, meaning "Rock Girl" in Hawaiian, launched from a 23-m (74-ft) deep starter tunnel on a mission to bore through almost 4.8 km (3 miles) of basalt bedrock. Contractor Southland/Mole JV is building the Kaneohe-Kailua wastewater conveyance tunnel for the city and council of Honolulu, which will improve waste water infrastructure by eliminating overflows during rain events.

The deep tunnel option was not the first design considered for the project. Preliminary plans called for a smaller tunnel traveling under the bay. As Kaneohe Bay is an environmentally sensitive area, a deep tunnel remained an attractive option. Richard Harada, of project consultant Wilson Okamoto Corp., explained the ultimate decision, "A number of factors were considered in making the decision to build a deep tunnel including reliability, construction costs, life cycle costs, environmental impacts, constructability and qualified

(Continued on page 19)

On April 30, 2015 in Honolulu, HI, a Robbins Main Beam TBM began a 4.6-km (2.8-mile) drive for a new sewer tunnel.

DC Water: Clean Rivers Project advancing

(Continued from page 08)

infiltrate rain on-site before it can reach the combined sewer system.

Carlton Ray, director of the DC Clean Rivers Project, added, "Lady Bird performed as well as projected—having a one-day best mark of 45 m (150 ft). In her best week, she tunneled 192 m (631 ft). This TBM's success means we are one step closer to a cleaner Anacostia River."

Lady Bird dug the southernmost segment of the Anacostia River Tunnel. The next section will be mined by another TBM named Nannie, who is preparing to begin her tunnel at a site near RFK Stadium. The Northeast Boundary Tunnel is the longest portion of tunnel, and that contract has yet to be awarded. At the northern tip of the tunnel system is the First Street Tunnel, a relatively short tunnel that will be mined by Lucy, and is designed as a flood protection project for the Bloomingdale and LeDroit Park neighborhoods.

Lady Bird removed approximately 1.1 Mt (1.2 million st) of material that she mined. This was hauled away in nearly 72,000 truckloads over the last two years. She built the tunnel with 28,189 pre-cast concrete segments which made up 4,027 full rings.

The cost of tunnel boring machines is included in the contract for each tunnel segment. Therefore, the TBMs are owned by the contractors for each tunnel portion. Lady Bird is the property of the contractor and can be extracted and used on another project. Lady Bird is being sold back to her German manufacturer, Herrenknecht. ■

Coming Up

2015 Cutting Edge: Urban Tunneling

Sept. 21-24, 2015
The Grand Hyatt, Denver, CO

http://www.ucaofsmecuttingedge.com

Crossrail: Project will serve growing population

(Continued from page 10)

2018. An estimated 200 million passengers will travel on Crossrail each year.

"This is a landmark moment for London that puts us a gigantic step closer to the launch of an absolutely vital new railway, which will hugely improve our ability to speedily move people across our city," Mayor Johnson said. "Crossrail has already created tens of thousands of jobs and helped boost the skills of many thousands of people, not just in the capital, but all around our great nation. It is a wonderful example of our nation's talent for engineering, a talent that must not be allowed to founder and that I hope will eventually be put to use on the construction of Crossrail 2."

Terry Morgan CBE, Crossrail chairman, said, "Crossrail is the most significant addition to London's transport network in a generation and one of the most ambitious infrastructure projects ever undertaken in the U.K. The completion of Crossrail tunneling is a truly significant milestone and would not have been possible without the support and commitment of London, our contractors and everyone who works on Crossrail."

London's population is set to grow from 8.4 million today to around 10 million by 2030. The government, the mayor of London and TfL are investing in Crossrail and other transport infrastructure to support access to jobs, education, housing and to boost economic growth. Crossrail is part of TfL's investment program.

Crossrail is a vital part of the government's commitment to invest record amounts in the rail network as part of its long-term economic plan. Between 2014 and 2019, more than £38 billion will be spent on improving and maintaining the U.K.'s railways.

Over the course of the project, it is estimated that Crossrail and its supply chain will support the equivalent of 55,000 full time jobs across the country.

A total of 84,300 jobs were supported last year across the U.K, through TfL's investment program and Crossrail. TfL and its suppliers have also created more than 5,000 apprenticeship roles since April 2009. ■

Robbins: TBM expected to be running in November

(Continued from page 16)

contractor availability."

During the tunnel design phase, it was decided that the tunnel route should travel inland and deeper underground in order to bypass one of the few residential areas along the alignment. Designers introduced an isolated curve in the tunnel alignment of 150 m (500 ft) radius, requiring the TBM to be designed with a unique backup system. There will also be operational procedures when crews navigate the tunnel curve, requiring the machine to be operated using half strokes rather than a full TBM stroke.

The curve is not the only unusual aspect of the tunnel. In fact, a tunnel on this scale has not been built in the Hawaiian Islands before. Everything from the logistics of the tunnel operation to pregrouting sections ahead of the TBM for ground water control are new to the Aloha state. Director of Southland, Tim Winn, elaborated, "There has not been a tunnel boring machine of this size in the Hawaiian Islands or a tunnel of this length. The tunnel is being driven from an active water treatment plant (WTP), and space is at a premium. There are also simultaneous contracts being performed there outside the scope of our work." He added that although there have been challenges, teamwork has been key: "Robbins Field Service has been extremely valuable during assembly and commissioning of the TBM." As of June 2015, the TBM had excavated more than 300 m (1,000 ft), and is boring at a rate of 12 to 15 m (40 to 50 ft) per day in basalt rock. Rock bolts, steel arches, wire mesh, and ring beams are being installed as necessary.

Upon completion, the deep tunnel will enhance water treatment capabilities and further aid in ceasing noncompliant, uncontrolled or moderately treated wastewater discharges. The main beam TBM is estimated to end its journey in eight to 10 months at the Kaneohe waste water pre-treatment facility. ■

Plans are in for new tunnel in Melbourne

The Victoria government in Australia has revealed the Melbourne Metro rail tunnel will run underneath the Yarra River, 11 m (36 ft) below the waterline.

Engineers on the multi-billion dollar project will use two tunnel boring machines (TBM), which will be buried underground.

The animation makes it look easy, but Transport Minister Jacinta Allen concedes tunneling under the Yarra will be a difficult job.

"Crossing the Yarra is one of the more complex parts of the Melbourne Metro rail project," Allen said.

Using the TBMs to cross the Yarra differs from what was proposed in the previous Metro Rail business case, which suggested an immersed tube tunnel or coffer dam construction, *9News.com.au* reported.

TBMs were seen as a less disruptive option than an immersed tube tunnel or coffer dam construction.

"Both of those approaches were seen as being more disruptive to the environment, more disruption to surrounding businesses," Allen said.

Pressure is on to get it right, with previous tunneling efforts under the Yarra proving problematic.

Construction of the Burnley Tunnel in 1999 resulted in serious leakage issues.

Public consultation is now underway. ■

Riyadh Metro: Includes 35 km (21 miles) of tunnels

(Continued from page 12)

more than 35 km (21 miles) of tunnels beneath the capital city.

Riyadh is one of the world's fastest-growing cities, with a population expected to increase 50 percent by 2035 to 7.5 million. The Riyadh Metro is part of a 25-year strategic plan prepared by the High Commission for the Development of Arriyadh to cater for this growth. When complete, the 176-km (109-mile), six-line driverless network will serve 400,000 passengers.

A global leader in the rail industry, Bechtel has successfully delivered some of the largest and most complex rail projects in the world, including the Channel Tunnel, High Speed 1, the San Francisco BART system and the Athens Metro. The company is currently providing project management services on Crossrail in London, UK, which is Europe's largest civil engineering project, and where (42 km) 26 miles of tunneling has just been completed on schedule. It is also working on the Rio de Janeiro Metro in Brazil and the Toronto-York Spadina Subway Extension in Canada. ■

RETC hosts more than 1,250 and 157 exhibitors in New Orleans, LA

Every two years, tunnelers and underground construction engineers, contractors, suppliers, designers and owners from around the world gather for the Rapid Excavation Tunneling Congress (RETC). In 2015, the conference was held in New Orleans, LA and more than 1,250 attendees were treated to 157 exhibitors and 113 technical presentations covering the breadth of the underground construction industry.

"We were very pleased with both the number of exhibits and the attendance, given that the event was just two weeks after the World Tunnel Congress (WTC) in Dubrovnik, Croatia. We received extremely positive feedback from those folks who attended both events. The lessons learned from the back-to-back events will help us when we present WTC2016 in April in San Francisco, CA," said SME Executive Director Dave Kanagy.

New Orleans

Hurricane Katrina was the costliest natural disaster in the United States history and was especially devastating to New Orleans, where 1,464 people were killed after the storm created 50 breaches in the drainage canal and levees. RETC attendees heard from two featured speakers about the recovery from the storm and a tour to Permanent Canal Closures and Pumps (PCCP) Project was available in conjunction with the conference.

For the past year, Traylor has been hard at work on the capstone of the PCCP Project for the U.S. Army Corps of Engineers. As part of PCCP Constructors, a

PCCP Project, a tour of the PCCP project was conducted in conjunction with RETC.

joint venture of Kiewit Louisiana Co., Traylor Bros. Inc., and the M.R. Pittman Group LLC, three permanent structures to block future hurricane storm surges to New Orleans from Lake Pontchartrain are being built. Not only must the new stations be designed to block surges from a 100-year storm, they must also take into account expected increases in the height of Lake Ponchartrain's water level during the next 50 years to account for the rising sea level caused by global warming and local subsidence. When the surge closures are operated during storms, the pumps will move 354 m^3/sec (12,500 cu ft/sec) of water from the 17th Street Canal into Lake Pontchartrain; 76 m^3/sec (2,700 cu ft/sec) from the Orleans Avenue Canal and 255 m^3/sec (9,000 cu ft/sec) from the London Ave. Canal. Temporary pumps and floodgates near the mouths of the three at-risk drainage canals (17th Street, Orleans Ave. and London Ave.) will stay in place until the team completes the permanent structures.

A major component of construction at each site is the pump station cofferdam. Unlike the closed cellular cofferdam cells Traylor has built in the past, these are being constructed with a relatively new open cell design developed by PND Engineering. The design utilizes fewer piles and is stable within a shorter diameter. The project is approximately 35 percent complete, with the preliminary site work and access roads completed. The team has also begun construction of the concrete structures. Project completion is scheduled for Sept. 27, 2016.

Angela DeSoto Duncan was the opening luncheon speaker. She is currently self-employed following a 24-year career with the Corps of Engineers and three-year career at Tetra Tech where she led nation-wide, multi-disciplinary teams of engineers, scientists and support staff for federal, state and local government clients. With the Corps, she was chief of a multidisciplinary branch responsible for the budget oversight, scheduling, cost estimating, design, real estate acquisition and environmental compliance documentation of the Hurricane Protection Offices' (HPO) five-year, fully funded, $7-billion Hurricane and Storm Damage Risk Reduction System (HSDRRS) program for the metropolitan New Orleans area. The HSDRRS program includes approximately 50 construction contracts consisting of levees,

floodwalls, sector gates, lift gates, flood control structures, pump station rehabilitation, control houses and urban drainage projects.

The RETC dinner featured a presentation from Lt. General Russel Honoré, USA (Ret.) that was sponsored by The Laborers' International Union of North America & Schiavone Construction Co., LLC.

Lt. General Honoré arrived in a Hurricane Katrina-battered New Orleans in 2005 and saved a city by taking swift charge of military relief efforts. Drawing on his 37 years of military experience, Gen. Honoré now brings his bold, no-nonsense leadership approach to businesses and organizations to help better prepare them for the challenges of the future. He addresses how the public and private sector can solve a broad array of issues — from jobs and energy to healthcare and technology — by emphasizing innovation, risk assessment and social entrepreneurship.

RETC exhibits

As managers of RETC and the North American Tunneling (NAT) Conference (held in off years from RETC), SME had a good sense of the needs of the tunneling community for this event. Because the conference had grown considerably since securing the hotel for this event, the exhibits and technical sessions were spread over multiple floors. Mike Rispin of Normet stated "I was a little worried about the two floors, but the traffic at our booth was excellent and we had quality conversations with many good people."

In 2016, the UCA of SME will manage the World Tunnel Congress in San Francisco, April 22-28. That event will bring the usual attendees from RETC and (NAT). Conference as well as international tunnelers from Europe, Asia and South America. As many as 2,500 attendees are expected with as many as 350 exhibit booths. WTC will be a one-time enhancement to the regularly scheduled NAT Conference, with the NAT Conference returning in 2018 to Washington, D.C.

Sessions

In addition to the top level speakers and vibrant exhibit floor, RETC always features the most comprehensive collection of technical sessions available, and the 2015 conference was no different. With 21 different tracks to choose

from, there was something of interest for everyone. The following is a look at a few of the 106 technical sessions that were presented during the conference.

A complete collection of the proceedings, including a CD for the papers, is available from SME for $149 for members, $139 for student members and $189 for nonmembers. The proceedings can be ordered from SME online at www.smenet.org/store or by calling SME at 303-948-4225, 1-800-763-3132.

Support of excavation for Roosevelt Station: Successful partnering overcomes challenging construction change, by Indra Banerjee and Ed Shorey, CH2M Hill; Hani Habib, Case Foundation Co; Elizabeth Lenker, McMillen Jacobs Associates and Brad Cowles, Sound Transit.

The Roosevelt Station is one of the two intermediate box excavations on the N125 Contract of Central Puget Sound Regional Transit Authority's Northgate Link Extension Project in Seattle, WA.

During design, the owner and designer settled on secant piles and tie backs for support of excavation. After award of the contract, the contractor expressed concerns about lead times for material procurement for the secant piles and advised that they were looking at alternative support methods. The contractor proposed a slurry diaphragm system to address their schedule concerns and improve upon the leakage and surface flatness requirements of the contract.

This paper presented the cooperative process undertaken by the owner, designer, construction manager and contractor to integrate the contractor's concept into the design, identify and address potential concerns with the design change, proactively engage the city's staff to streamline the permit review process and successfully complete the installation of slurry diaphragm wall system. Issues and challenges that were encountered during development and execution of the slurry diaphragm wall work are identified along with the steps taken to mitigate them.

Continuing a legacy of large-diameter hard rock tunneling in Chicago — The Des Plaines inflow tunnel, by Cary Hirner, Faruk Oksuz, Brian Gettinger and Brian Glynn of Black & Veatch Corp. with Kevin Fitzpatrick and Carmen Scalise,

Metropolitan Water Reclamation District of Greater Chicago.

The Metropolitan Water Reclamation District of Greater Chicago's Des Plaines inflow tunnel will provide direct conveyance of 317 m³/sec (11,200 cu ft/sec) of water from the Des Plaines Tunnel System to the McCook Reservoir. The project will alleviate a bottleneck in the Tunnel and Reservoir Plan (TARP) system by creating a second major tunnel connection to the 38 GL (10-billion gal) McCook Reservoir. The 1.6-km (1-mile) long, 6.1-m (20-ft) diameter hard rock tunnel will include live connections to the existing Des Plaines Tunnel System and to the operating McCook Reservoir as well as a gate shaft and an energy dissipation structure in the reservoir with low clearance crossings.

PPP mode for procurement of Lines 2 and 4 of Lima Metro, by Andrea Lavagno and Nicola Ruga, Geodata Engineering and Christy García Godos Naveda, Proinversión presented the paper about the new rail lines in Perus Lima Metro.

The new (and first entirely underground) lines 2 and 4 of the Metro Lima network represent a huge challenge in Peruvian infrastructure standards, even if the country is strongly committed to the public-private partnership (PPP) promoted by its pro-business organism Proinversión. With a U.S. $6.5-billion design build finance operate transfer-type contract, co-financed by Peruvian state, the project involves 35 stations and 35 km (21 miles) of fully UTO underground lines, to be drilled mainly by tunnel boring machines in a country with little or no experience in urban tunneling. The concession process was accomplished successfully in an outstanding 20-month period, from the consultancy assignment to the signing of the concession contract.

Challenges and methods utilized to excavate rock for an escalator incline through a luxury high-rise building in Manhattan, by Adam Smith and Anisa Dhimarko, Skanska USA Civil Northeast and James Collins, AECOM.

As part of the ongoing 2nd Avenue Subway extension program MTA Capital Construction (MTACC) contracted with Skanska/Traylor Joint Venture (STJV) to perform mining and structural concrete work for the 86th St. Station. One of the key components, as well as one of the highest risk pieces of work on the 86th St. Station contract, was to excavate rock through an existing luxury high-rise apartment building to make way for the escalator entrance. This work required temporary supporting the building to allow for the removal

and subsequent replacement of main support columns that interfered with the future escalators. The authors discussed the successful engineering, planning and execution phases of this critical aspect of the excavation and underpinning of the high rise building.

Ground freezing for tunnel cross passages: First application in North America by David M. Mueller, Joseph A. Sopko and Robert Chamberland, Moretrench American Corp. and Roger B. Storry, Bouygues Travaux Publics.

Ground freezing was used for the first time in North America to freeze two 2.8 m (9 ft) diameter cross passages for the Port of Miami Tunnel. While ground freezing has been used for similar construction in Europe and Asia, this was the first application in North America. This project was complicated by the extremely porous subsea soils. To reduce the permeability of these soils and rock, an initial grouting program was implemented from the ground and channel surfaces.

Two rows of horizontal freeze pipes were drilled and installed to form the frozen cylinders for excavation support and ground water control for cross passage construction. The refrigeration system used to circulate the cooling medium was located at the ground surface and supplied to the cross passages via supply and return manifolds and a specially designed pumping system.

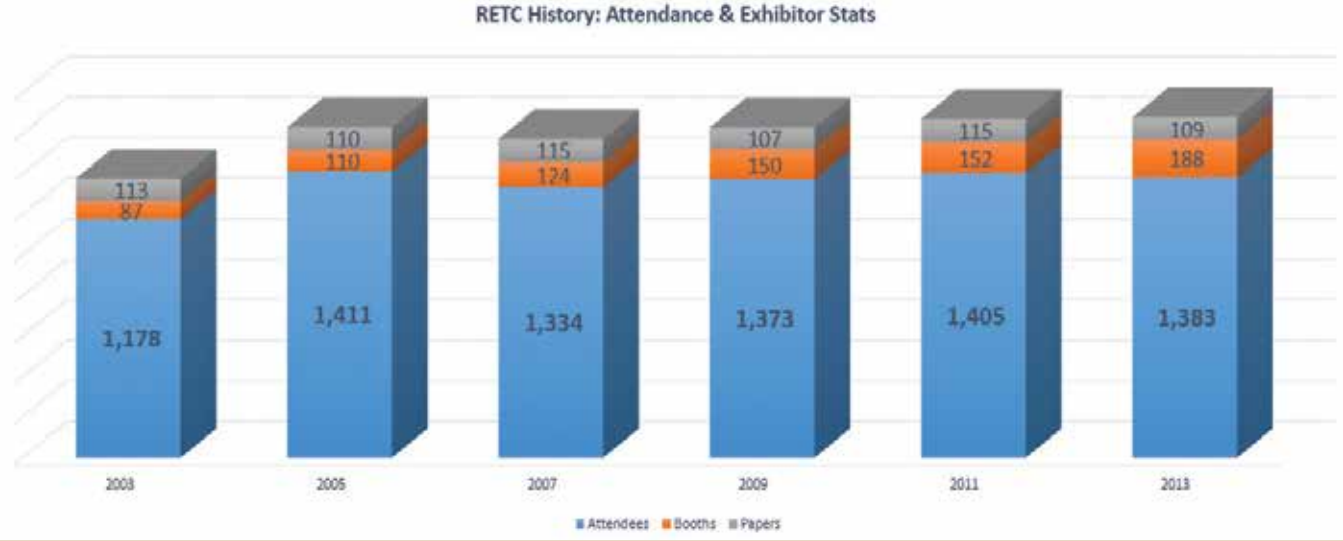
An extensive system of instrumentation was installed to monitor ground temperatures, soil and rock water pressures, coolant flow rates and pressures and process information from the refrigeration plants.

This paper discussed the grouting approach, freezing system drilling and installation; freeze monitoring and the excavation and completion process of a very successful project. Guidelines and recommendations for frozen cross passage construction are summarized.

Delivery of Crossrail Western Tunnels by Andy Alder and Dan Callaghan, CH2M Hill.

The Crossrail Project is building a new railway for London and the south-east of England, and is Europe's largest construction project. The construction of Crossrail has been split into a number of contracts, each tasked with delivering a section of the project. This paper specifically reviews the works undertaken on the C300/410 Western Tunnels contract, which involved the construction of

RETC has grown in the past decade to become a must-attend event for the tunneling industry.



6.8 km (4 miles) of twin-bore running tunnel constructed with a tunnel boring machine (TBM), and nearly 2 km (1 mile) of shotcrete-lined (SCL) tunnels.

When the project is complete the Crossrail trains will run more than 122 km (75 miles) of railway, running east-west below central London and connecting to suburban areas to the west and east of London. 21 km (13 miles) of the Crossrail route are being constructed underground and eight of the new stations are also being built underground.

The population of London is forecast to grow significantly. And to support this, the objectives of the Crossrail project are:

- To relieve congestion on the existing London Underground network, particularly the Central Line.
- To provide an additional 10 percent capacity to London's rail-based public transport system.
- To reduce journey times for people commuting into, and

across, London.
- To provide improved connections to Heathrow Airport, the West End and the business districts of the City and Canary Wharf.
- To support regeneration and connect to areas designated for additional housing provision.

Crossrail is Europe's largest construction project, with a funding envelope of £14.8 billion.

Seattle Fire Department's approach to tunnel rescue, by Frank Brennan, Seattle Fire Department.

For more than a decade, the Seattle Fire Department has successfully partnered with other public agencies, labor organizations and private contractors to develop an emergency response structure tailored to the specific conditions of the various tunneling and underground projects in Seattle, WA. This cooperative process has allowed the agency to develop a model and build a system for effective delivery of fire, rescue and emergency medical services into the underground environment that shares the burden of providing such resource intensive services. This paper outlined the process the Seattle Fire Department undertook to establish those relationships as well as the roles of its partners, development of its emergency response model and the supporting training program.

Tale of two cities — Subaqueous tunneling in London and New York City, 1879 to 1910, by Vincent Tirolo Jr., Arup.

Subaqueous shield tunnel construction began in London in 1828 when construction of Marc and Isambard Brunel's Thames Tunnel began. In London, Peter Barlow, James Henry Greathead, Benjamin Baker and Charles Jacobs developed tunneling practice to include circular shields, hydraulic jacks, cast iron liners and compressed air. In New York City in 1879, DeWitt Clinton Haskins attempted to cross the Hudson River using compressed air but without a shield.

A blow in 1880 caused 20 sandhog fatalities. Mining continued, but the work was abandoned in 1888 for lack of funds.

In London, Barlow and Greathead had successfully mined the 2.178 m (7 ft) diameter Tower Tunnel under the Thames using a circular shield, propelled by screw jacks reacting against a cast iron segmental initial lining. In 1889, Austin Corbin, president of the LIRR, invited Charles M. Jacobs of London to New York. In 1890, work resumed on the Hudson River when S. Pearson & Son of London assumed the construction contract. Sir Ernest Moir designed the shield for this work and introduced the first medical lock.

These events started the collaborative association of the tunneling engineering in both London and New York that would last more than 30 years and culminate with the completion of the Pennsylvania Railroad Tunnels under the Hudson and East Rivers in 1910. Concurrent with this mining collaboration, Werner von Siemens in Germany, Frank J. Sprague in the United States and others were developing electric traction systems into reliable systems that would make subaqueous railway tunnels possible.

WTC 2016

The UCA of SME will host the ITA-AITES World Tunnel Congress, WTC2016, April 22-28 at the Moscone Center in San Francisco, CA.

It will be the must-attend event of the year. WTC is the leading international conference each year. When it comes to the United States in 2016, it will feature as many as 600 technical presentations and 250 exhibitors. Between 2,500 and 3,000 people are expected to attend the conference designed especially for tunnelers representing owners, contractors, engineers and suppliers.

More information about WTC can be found at the conference website at www.wtc2016.us. ■

San Francisco to host ITA World Tunnel Congress 2016

by Harvey Parker and Amanda Elioff

The International Tunnelling and Underground Space Association (ITA) is a nonprofit organization that represents all aspects of the tunneling and underground space industry worldwide. Next year, the ITA will be holding its annual World Tunnel Congress (WTC) in San Francisco, CA, April 22-28, 2016. The ITA's mission is to be the leading international organization advancing the entire industry and promoting the use of tunnels and underground space through knowledge-sharing and application of technology. This article updates a series of articles about the ITA prepared in 2007 by Harvey Parker, former president of the ITA, in anticipation of the next WTC in San Francisco.

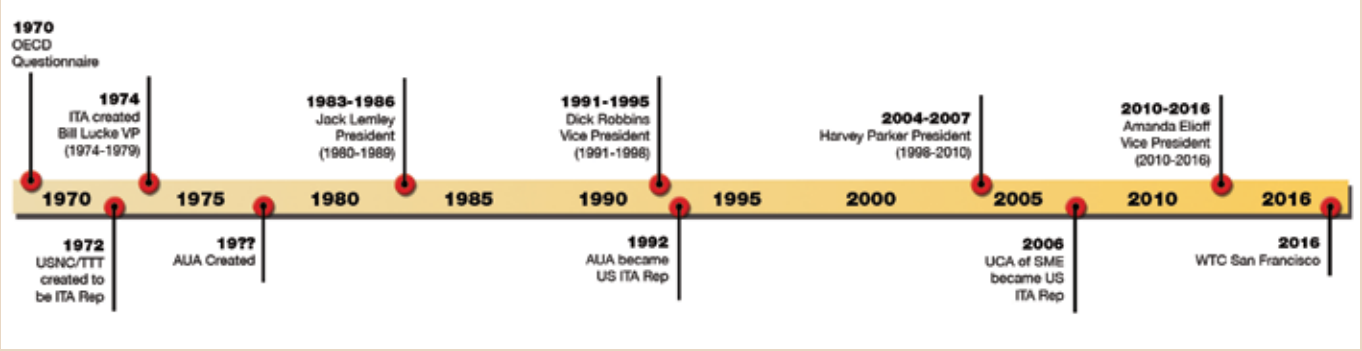
ITA accomplishes its goals through a range of activities that includes organizing conferences, workshops and meetings, working group and committee studies, training, experiments and other activities. ITA is also involved in the publication of proceedings, reports, and guideline documents as well as facilitating interaction among its membership and with sister organizations and decision makers. ITA currently includes 73 member nations and several hundred affiliate members, including 15 prime sponsors and 63 supporters. ITA's membership is comprised of member nations as well as sponsors and affiliate members.

The United States has had a prominent role in ITA since its 1974 inception, when it was formed as a result of a worldwide survey conducted in the early 1970s by the Organization for Economic Cooperation and Developmentt (OECD). Bill Lucke, from the U.S., who was in charge of tunnels for the U.S. Federal Railroad Administration, was a member of the organizing committee that created ITA and became a vice president of ITA. Jack Lemley served as president of ITA from 1983 to 1986. Dick Robbins was active in ITA and served for many years as a member of the ITA's Executive Council and as first vice president. Harvey Parker served as president of ITA from 2004 to 2007. Amanda Elioff is currently serving on the executive council as a vice president. Over the years, the official U.S. representative has changed from the U.S. National Committee on Tunneling Technology (U.S.NC/

U.S. delegate Randy Essex attending ITA General Assembly.

Figure 1

Timeline of U.S. involvement in ITA.



TT), to the American Underground Construction Association (AUA) to the current representative, the Underground Construction Association of SME (UCA of SME). A summary timeline of U.S. executive leadership and representation in ITA is presented in Fig. 1.

Moreover, there are many other individuals and companies from the United States that have contributed significantly to the activities and the success of ITA. There have been several active working group animateurs (essentially chairpersons) from the United States, and there have been significant contributions from many other individuals as well as companies from the U.S. Every known U.S. person contributing to ITA prior to 2007 was listed in Parker (**T&UC**, June 2007 and September 2007). Several U.S. engineers are currently serving ITA in a leadership role. In addition to Amanda Elioff, Henry Russell and Brian Fulcher are animateur and vice animateur, respectively, of ITA working groups. In addition to those who are elected by the ITA, there are numerous U.S. professionals currently contributing to ITA through UCA.

How is ITA organized?

ITA has something for everyone involved in the tunnel and underground space industry. ITA is an organization of member nations with a wide-ranging geographic representation throughout the world. The ITA Secretariat is currently located on the university campus of L'Ecole Polytechnique Fédérale de Lausanne (EPFL) in Lausanne, Switzerland. Each member nation is represented by one organization. The UCA of SME is the official organization representing the United States. SME Executive Director Dave Kanagy and Tim Reagan, SME director of operations, are providing SME oversight to the U.S. activities

Table 1

Diversity of members of ITA and UCA.

- Owners, public and private.
- Owners of engineering agencies.
- Private and governmental planners.
- Engineering designers & consultants.
- Academics and researchers.
- Heavy construction contractors.
- Specialty contractors and consultants, such as microtunnelling or shotcrete or freezing contractors.
- Material and equipment suppliers.
- Lawyers and politicians.
- Economists and financiers.
- Emergency response personnel.
- Mine owners and mining operators.

with ITA. Randy Essex is the official delegate from the U.S. to the ITA's General Assembly, the ITA body that meets annually at the ITA's World Tunnel Congress.

In Canada and Mexico, the comparable organizations are the Tunnelling Association of Canada and the Asociación Mexicana de Ingeniería de Túneles y Obras Subterráneas. It is estimated that the combined network of ITA extends through all member nations to some 20,000 people. The individuals participating in ITA are very diverse, coming from all walks of life, backgrounds, industries and professions. This diversity of professional culture is shown in Table 1.

Figure 2

ITA working group publication.

In addition to the main member nations, ITA also has 300 corporate or individual affiliate members. Of these, the U.S. has 14 corporate members and several individual members. There are also two levels of sponsorship, the prime sponsor level and supporter level. The U.S. has one prime sponsor, The Robbins Company, and five supporters: Harvey Parker & Associates, Inc., ARUP, Aldea Services, LLC, Parsons

T&UC SEPTEMBER 2015 31

Brinckerhoff, and W.R. Grace.

ITA organizes and sponsors numerous meetings, workshops and training sessions all over the world each year on the full range of topics associated with tunnels and underground space. During annual meetings, and now between meetings due to email and other forms of communication, ITA's working groups meet and develop reports and guidelines for their fields of expertise (Table 2). Working groups are composed of individuals designated by the member nations as well as volunteers from the industry at large. Table 2 is a list of the currently active working groups and Fig. 2 illustrates the cover page of a recent ITA Working Group publication.

Recently, several committees have been formed to address issues of importance on a different level than what can be accomplished by working groups. Committees are composed of corporations and organizations interested in the particular topic. Unlike working group members, most corporate committee members pay a fee for their membership. The committees are:

- Committee on Education and Training (ITA-CET) organizes and conducts training courses and

Table 2

ITA Working Groups and U.S. representatives.

Working Group
Young Members Group
WG – 2 Research
WG – 3 Contractual Practices
WG – 5 Health and Safety in Works
WG – 6 Maintenance and Repair of Underground Structures
WG – 9 Seismic Effects
WG – 11 Immersed and Floating Tunnels
WG – 12 Sprayed Concrete
WG – 14 Mechanized Tunnelling
WG – 15 Underground and Environment
WG – 17 Long Tunnels at Depth
WG – 19 Conventional Tunnelling
WG – 20 Urban Problems - Underground Solutions
WG – 21 Life Cycle Asset Management
*Designated representative

Table 3

Publication of proceedings, reports and documents.

Publications available from publishers.
• Proceedings of all World Tunnel Congresses.
• Scientific Journal: Tunnels & Underground Space Technology (TUST) available to all ITA Members.
Electronic newsletter "ita@news"
• Covers activities of member nations, prime sponsors and supporters and relevant news regarding tunneling and underground space, sent every two months.
Publications and presentations available from ITA Web site www.ita-aites.org
• Working group and committee reports (published in TUST but the individual reports are available for free on the ITA Web site, www.ita-aites.org).
Position papers
• Papers and presentations from all ITA training sessions.
• Selected workshop and conference proceedings (papers and presentations), CD-ROM of all formal ITA publications from complete 30-year history.

and training to help with financing of training worldwide. In addition, ITA has established a university network that is nurtured, proactive, extended and actively promoted, including the endorsement of university masters courses.

- ITA COSUF is the Centre of Excellence for world-wide exchange of information and know-how regarding safety and security of underground facilities in operation. The committee's scope concerns the operational safety in tunnels and other underground facilities as well as security. ITA COSUF conducts workshops, has published more than 50 documents and conducts award ceremonies.
- Committee on Underground Space (CUS) promotes the use of underground space to help cities cope with urban challenges including shortage of space above ground, sustainable development and resilience. CUS forms links with relevant decision makers and sister organizations such as the United Nations (an NGO with the UN since 1987), the European Union, World Bank and Development Banks worldwide, as well as owners and planners of tunnels and underground space.

ITA has also developed a close relationship with the industry through the most recently created committee, ITATECH, which is a collective group of all prime sponsors and ITA supporters. ITA TECH has established many activity groups which work on summarizing and expanding the state of practice of various tunneling tasks.

Last year, the ITA established a young member forum. The aim of the group is to:

- Provide a technical networking platform within ITA for young professionals and students.
- Bridge the gap between generations and to network across all experience levels in the industry.
- To look after the next generation of tunnelling professionals and to pass on

the aims and ideals of the ITA.

This year, the ITA will also host the International Tunnelling Awards. With the growth of infrastructure needs and requirements for better use of space and resources, the development of underground options has often provided excellent solutions to these challenges. As part of this endeavor, the ITA has taken the initiative to launch its own dedicated Tunnelling Awards to identify outstanding achievements in the field of tunneling and underground space use, and to provide international recognition to these remarkable contributions. The awards ceremonies will be held in different locations worldwide, with the first annual event (Fig. 3) to be held at the Hagerbach Test Facility near Zurich in Switzerland on Nov. 19, 2015.

Figure 3

ITA awards ceremony to be held at the Hagerbach Test Facility near Zurich, Switzerland.

ITA continually publishes the results of its activities as outlined in Table 3. It publishes all of its information for the benefit of its members and the public. An enormous amount of valuable information has been published and archived by ITA. Essentially, all the available documents published in the last 40-plus years are available on the ITA website free of charge.

Finally, ITA is a forum for the exchange of information among its members and for informing official bodies, such as the United Nations, The European Union, governments, owners and planners of the public at large, about, benefits of tunnels and underground space.

U.S. participation in ITA strengthens UCA

All members of the UCA of SME may participate in ITA activities, and participation in ITA activities benefits both ITA and UCA. UCA designates one person to be the official delegate to each working group. However, one can express interest in an ITA working group and become a corresponding member. As a corresponding member, individuals can contribute to working group meetings and communications. Working groups hold a meeting during every WTC. Travel to ITA conferences

is good because of the friendships made during these meetings, and technology transfer is easier face-to-face. Professional activities and technology transfer do involve work and sometimes travel. However, one can also contribute to UCA-ITA activities by email and/or FTP sites administered by each working group.

U.S. hosting of annual ITA World Tunnel Congresses

To date, the U.S. has hosted several executive council meetings, two meetings of the annual ITA World WTC and is the host of the next WTC in San Francisco. The first U.S. WTC was held in 1979 in Atlanta, GA and the second in 1996 in Washington, DC. Although ITA had emphasized the environment since its beginning, the theme of the Washington, D.C. conference, sustainable development, was the first time an ITA conference highlighted this topic. The WTC2016 conference theme for San Francisco is "Uniting Our Industry." UCA is working very hard to organize and make this an extraordinary event for all in the industry.

Conclusion and challenge

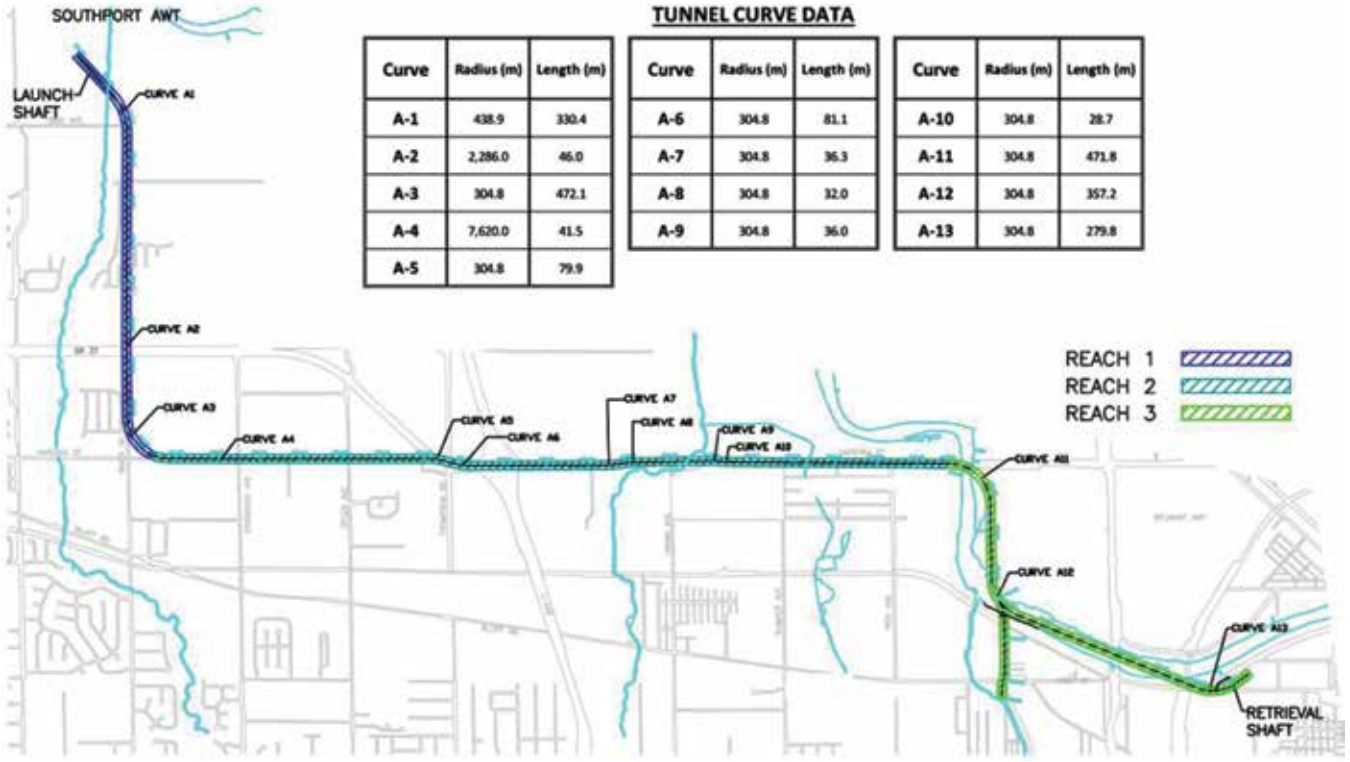
The U.S. is only one of the many countries to have strongly contributed to the success of ITA. However, the U.S. and, especially UCA members, can be proud because the U.S. has a wonderful heritage and legacy in the success of ITA, which should be built upon and continued by the UCA and its members. The authors recommend involvement by individuals and, companies. ITA is a great platform to demonstrate your successes and provides good marketing and networking opportunities. ITA also provides a special opportunity for young professionals. Join us in 2016 for the WTC in San Francisco. By joining and participating, you will reap the numerous advantages of being an active member of the "ITA Family." ■

FEATURE ARTICLE

TBM mining for the Deep Rock Tunnel Connector project

Figure 1

Overall alignment of the Indianapolis Deep Rock Tunnel Connector project.



TUNNEL CURVE DATA

Curve	Radius (m)	Length (m)
A-1	438.9	330.4
A-2	2,286.0	46.0
A-3	304.8	472.1
A-4	7,620.0	41.5
A-5	304.8	79.9

Curve	Radius (m)	Length (m)
A-6	304.8	81.1
A-7	304.8	36.3
A-8	304.8	32.0
A-9	304.8	36.0

Curve	Radius (m)	Length (m)
A-10	304.8	28.7
A-11	304.8	471.8
A-12	304.8	357.2
A-13	304.8	279.8

The Deep Rock Tunnel Connector project is being constructed by the S-K JV, a joint venture between the J.F. Shea Construction and the Kiewit Infrastructure Co. As bid, it was a $179-million dollar project being built to address combined sewer overflows into the White River in the city of Indianapolis. Currently, the project is on schedule and budget for excavating and lining of the tunnel with completion in May of 2017.

Michael Stolkin, Eric Haacke and Mark Guay

Michael Stolkin and Eric Haacke, member UCA of SME, are engineer and project engineer, J.F. Shea Construction respectively, and **Mark Guay** is resident engineer, AECOM, email eric.haacke@jfshea.com.

Geology

The Deep Rock Tunnel Connector project (DRTC) is located in the city of Indianapolis in Marion County, IN. Marion County is located between two regional bedrock structures, the Kankakee Arch to the northeast and the Illinois Basin to the southwest. Devonian and Silurian carbonate rock underlie most of Indianapolis and the White River valleys where the DRTC is located. New Albany Formation shale was encountered at elevations ranging from approximately 167 to 190 m (550 to 625 ft) along most of the DRTC alignment. Additional bedrock formations underlie the New Albany shale, including North Vernon Formation limestone and Vernon Fork and Geneva. The DRTC tunnel is excavated within the Vernon Fork Formation, the Geneva Formation, or a mixed face of both formations.

The bedrock within the tunnel zone exhibits vertical

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KIEWIT.COM/FOUNDATIONS

Figure 2

Rebuild of TBM.

to subvertical, northern and eastern trending, very close to a widely spaced joint structure, with horizontal to subhorizontal bedding trends to the east. The rock is moderately strong to very strong. Cerchar Abrasiveness Index (CAI) testing was conducted and yielded a value range between 0.1 and 2.9. Approximately 56 percent of the data indicated very low to low abrasiveness, 31 percent had medium abrasiveness, and 3 percent exhibited high abrasiveness.

Safety

A typical shift begins with an all-hands safety meeting held at the surface before heading to the shaft and then underground. This is a free exchange of information between employees and supervision to speak about any safety related topics relevant to the work and discuss and remind all involved about concerns and issues. With few exceptions, the day shift safety meeting is attended by both the project manager and project superintendent, who have active speaking roles and are visibly engaged with the meeting. After the meeting is adjourned, the shift supervisor ensures that the tunnel system is safe for entry by conducting and reviewing a variety of gas readings such as oxygen percentage of the tunnel atmosphere, and carbon monoxide, nitrogen, hydrogen sulfide, etc. This tunnel is being excavated in rock that contains water with dissolved hydrogen sulfide gas, and also has areas that were identified with small oil seeps. Because of the possibility of gasses during excavation, the TBM was equipped with a gas detection system that monitored methane, hydrogen sulfide and oxygen. The methane detectors were interlocked with the tunnel boring machine (TBM) power system and would shut down the TBM power if gas concentrations at 10 percent of the LEL were identified.

Underground, the shifter is responsible for knowing the locations of all personnel along the tunnel alignment and the working heading. Communication phones are placed along the tunnel alignment as well as at all boosters and any permanent equipment set in the tunnel. To ensure all workers are aware of the startup of the conveyor system and the TBM, a klaxon and strobe light system was employed. If crew members are undertaking maintenance in the cutterhead, the head is locked out by the TBM operator who controls the only key, and thereafter is responsible for inspecting the head and ensuring it is clear of workers before returning to normal operating status.

Contractually, the project is under an owner controlled insurance program (OCIP) and to date has been viewed as being very successful, but not without plenty of involvement from the SK-JV from the level of labor through upper management.

Survey control and TBM guidance

Initial survey control for the starter tunnel was developed from a control dropped down the starter tunnel shaft and transferred to a variety of points along the alignment as the drill-and-blast development of the starter tunnel progressed. Before setting up the TBM, an accurate survey in the starter tunnel was undertaken and again a variety of points set for the TBM to back sight on. The network of points installed was developed using a north seeking gyro with accuracy to one second.

The north seeking gyro (DMT Gyro Mat 2000) was utilized along the tunnel alignment to establish control lines and re-adjust control that the TBM guidance system back-sighted on. The interval of gyro measurements taken was every fifth traverse leg, which was sufficient to maintain horizontal tolerances. Horizontal tolerances along the tunnel right of way were plus/minus 30.48 cm (12 in.), with tighter tolerances as the tunnel approached various shafts along the route. Three utility shafts raise bored to 3.05 m (10 ft) in diameter were completed along the tunnel after the TBM mined beyond their locations, and with either the completed raise bore or the pilot hole, the opportunity to tie the tunnel survey into surface control was also undertaken and to verify the PPS Guidance System being used on the TBM. With the use of the north seeking gyro, the availability of drop holes and shafts along the alignment, and experienced personnel, tunnel alignment never became problematic.

TBM

The TBM used on the DRTC, Robbins Model 203–205, was originally constructed by Robbins in 1974 and has been used on a variety of projects by contractors, including J.F. Shea, since then. The TBM and trailing gear have been altered over the years to accommodate the tunnel contracts and keep pace with technology. The DRTC project is no exception to this. Below is a list of the prior projects the TBM has completed.

- MTA — 63rd Street Tunnel project, New York City (completed 1979) 6.1 m (20 ft) diameter.
- Montreal, Canada — Sewer tunnel (completed 1986) 6.1 m (20 ft) diameter.
- NYCDEP — Brooklyn Water tunnel (completed 1986) 6.71 m (22 ft) diameter.
- Fall River, MA — Fall River CSO tunnel (completed 2003) 6.71 m (22 ft) diameter.
- MTA — 2nd Avenue Subway C-26002, NY (completed 2011), 6.71 m (22 ft) diameter.

Prior to bidding and after award, there were a number of concerns to deal with when planning to refurbish the TBM. In order to maximize production geology described in the bid, documents were further reviewed. Geology was anticipated to be very favorable in achieving high production rates. Another item given consideration was the 762-m (2,500-ft) long Pleasant Run tunnel spur off of the main DRTC alignment, as shown in Fig. 1. This would require backing out the TBM

Figure 3

Robbins cutterhead.

Figure 4

TBM trailing gear.

to continue along the main tunnel alignment. And as a follow on to expected good geology and high excavation rates, a conveyor system with high capacity would also be needed.

In the process of refurbishing the TBM (Fig. 2), a new cutterhead was designed in conjunction with Robbins and fabricated by Robbins. It made use of 48.26 cm (19 in.) back loading cutters, had a flat face, no face buckets, and oversize peripheral buckets. This enabled good cutting of the rock, and with the space between the cutter head face and rock face, plenty of room for material to fall with minimal regrinding. The 48.26 cm (19 in.) cutters would also offer the advantage of needing fewer cutter changes while being able to withstand the high loads the machine would be capable of. Also incorporated into the design was the likely need to disassemble the cutterhead in order to back out the TBM. To further save time, the head was designed in three main sections that were bolted to one another. The main center section was circular and was bolted onto the cutterhead support and bearing assembly. Onto this the two outer portions were attached and secured by bolted connections. As hoped, the cutterhead performed exceptionally well with little regrind, offered good internal access and cleaned material away from invert exceptionally well.

To minimize production downtime, power to the cutterhead required attention as well, so the drive system was evaluated, replaced and upgraded. Clutch packs that were previously used were eliminated. Using the VFD system made doing away with the air clutches a viable option as they were viewed as failure prone from other work experiences. On a practical note, the cutterhead speed was limited to a maximum of 8 rpm so that gauge cutter bearing life could be maximized. With air clutches eliminated from the driveline, torque limiters were inserted to provide a level of safety. These were viewed as especially robust, having few moving parts and only needed if the cutterhead should lock up unexpectedly or a problem with the pinion and bull gear meshing arose. They were set at a specific loading and would come into play should loadings be exceeded and thereby offer a level of safety in the drive system before damage could occur. So, power to the cutterhead began with VFDs powering each motor, and thereafter through the torque limiter, followed by the planetary reducers, and then the pinion/bull gear which is directly attached to the cutterhead bearing assembly.

A well-designed cutterhead, as shown in Fig. 3, and geology along with the 48.26-cm (19-in.) cutters resulted in very few cutter changes over the length of the excavation. The drive system, from the VFDs to the electrical motors and associated driveline components were problem-free, as planned. These small planning details and execution proved to be quite beneficial in allowing S-K JV to take advantage of the geology with high production rates in areas of the tunnel alignment that were not impacted by grouting downtime.

Figure 5

Rock support at Pleasant Run.

General TBM overview

The main bearing and seal assembly consisted of a high-capacity, asymmetrical, tapered roller bearing, 35.05 cm (138 in.) outside diameter, ring gear and inner/outer seal assemblies. The main drive consists of water-cooled

electric motors with planetary gear reducers to drive a common internal hardened ring gear.

Cutterhead horsepower and drive system details:

- Cutterhead torque: 3,261,741 Nm (2,405,737 ft-lbs).
- Cutterhead rotation speed: 0 to 8 rpm.
- Cutterhead reversibility: The cutterhead has the ability to be reversed.
- Machine thrust: 1,356,241 kg (2,990,000 lbs).
- Thrust per cutter: 29,483 kg (65,000 lbs) per cutter.
- Total weight of TBM: 408,233 kg (900,000 lbs).
- The machine has a total of 16 trailing gear decks, as shown in Fig. 4.

After a year of hard work, the final loads of equipment were shipped to Indianapolis for assembly in the starter tunnel. The final assembly of the TBM took less than three months and mining began in March 2013.

Figure 6

Conveyor system on the surface.

Probe drilling and grouting

Geology report characterizing water inflows along the tunnel alignment indicated that most of the water would be expected in the second half of the drive; with the first half relatively dry. Contract bid documents also mandated grouting when water inflows through a probe hole exceeded 378 L/min (100 gpm) and, if inflows exceeded 189 L/min (50 gpm), the engineer to be notified and direction to be provided as to whether or not to grout. Along with requirements for grouting, the design also called for lengths of the tunnel to be unlined, but still a strict water inflow requirement had to be adhered to.

A ring-mounted probe drill was mounted after the roof drills on the drilling platform. The drills were designed to probe in line and articulated to drill multiple patterns. Probe holes were drilled along the entire tunnel alignment. The holes were drilled utilizing two Boart Longyear HD150 hydraulic drills.

A Hany high shear colloidal mixer of approximately 19820 L/h (5,236 gph) capacity was used. After setting up the plant and header pipes, the grout material was mixed in accordance with the mix design. The standard mix started with a 4:1 water-cement ratio by weight. Refusal grouting was considered complete when the pressure gauge reached 6.89 bar (100 psi) over static water pressure. Secondary holes were drilled to ensure that the water has been shut off in the probe zone.

Ground control

While the cutterhead design stabilized the face, temporary ground control was achieved with a hydraulically activated roof shield and side support structures on each side of the machine. The roof support was equipped with support structures on each side of the machine. The roof support was equipped with cut outs in four locations to allow for rock bolt installation ground stabilization equipment. Omega expandable friction bolts supplied by Dwidag were installed to secure unstable rock, as shown in Fig. 5.

Two roof drill units on either side of the main beam allowed independent rock drilling simultaneous to TBM boring. The TBM was a shield machine that provided temporary support in unstable ground and maintained the integrity of the bore by keeping the roof and side supports extended against the tunnel surface until the ground support was installed. The entire shield extended 6.1 m (20 ft) and was slotted with opening extending 50.8 mm (2 in.) from the end of the shield towards the face approximately 127 mm (5 in.) wide to allow for the installation of ground support.

Muck handling

Excavated rock was removed with a horizontal and vertical conveyor system with more than 10,668 tunnel m (35,000 ft) on conveyer installed in the tunnel, another 76 m (250 ft) going up the shaft and the ability to store or let out 609 m (2,000 ft) of conveyor from a surface-mounted storage unit. The belt was a 914-mm (36-in.) wide, three-ply belt with a 800 PIW rating and 3/16 in. wearing surface. At the shaft bottom, the loaded belt discharged onto a vertical bucket belt to be hauled up the shaft and deposited onto a stacking conveyor.

Power to the loaded horizontal belt was supplied through a series of boosters with 149-kW (200-hp) drive assemblies. The unloaded belt was powered by return boosters, again with 149-kW (200-hp) drives. The surface storage unit, as shown in Fig. 6, provided easy access to the belt for inspection, and allowed the belt to be loaded into the system without having to lower rolls of conveyor down into the shaft or starter tunnel. Splices were done by trained crews at the surface in a sheltered enclosure, and mechanical splices were kept to an absolute minimum, with mechanical splices replaced by vulcanized splices. A 37-kW (50-hp) electric motor that was excited by a small variable frequency drive was used to supply tension in the system at the storage unit, and again, with no moving parts other than the cable due to the use of the VFDs. Each drive assembly underground was powered by individual VFDs as well. Each drive was monitored at the surface by PLC systems tied into a fiberoptic cable and ethernet access was available from the surface as well. For the system startup and under loaded conditions, various parameters such as timing between boosters, ramp up speeds, belt speeds and motor loads, could be monitored and then altered from an office setting topside, allowing for changes to the system as the belt length increased.

The horizontal belt also had to overcome more than just the linear quantity of belt installed. As noted earlier, the tunnel also had five curves, two 90° curves with 304 m (1,000 ft) radii, and the remaining three at varying lengths and curve date. The horizontal belt carrying structure required the use of the self-aligning troughing rollers in curves to keep belt tensions within a managable range.

Mining

Mining production commenced at the southern end of the alignment, which is located at the Southport AWT facility and continued north to the intersection of South West Street and South White River Parkway East Drive. The north end of the DRTC segment is at the south end of the Fall Creek/White River (FCWR) tunnel project segment.

The 12.5-km (8-mile) tunnel was divided into three sections (in proper production sequence):

- Reach 1 - 2,920 m (9,579 ft).
- Reach 2 - 5,784 m (18,976 ft).
- Reach 3 - (US #3 to wye) 1,242 m (4,076 ft).
- Pleasant Run Extension - 709 m (2,326 ft).
- Reach 3 (wye to Retrieval Shaft) - 1,897 m (6,224 ft).

Once the Pleasant Run Extension was completed, utilities were removed and the TBM returned to the wye. Concurrently, TBM/belt maintenance was preformed, and preparations for the bulkhead were made. Once the bulkhead was installed, a concrete plug was placed to tunnel springline to provide adequate strength for the grippers. Once mining advanced past the wye section, the plug was removed by drill-and-blast methods and mining resumed to the retrieval shaft.

Using the aforementioned equipment and methods, the S-K JV team has made many achievements, including setting three production world records. These records are:

- Most feet mined in one day, 124.93 m (409.89 ft).
- Most feet mined in one week, 515.12 m (1,690.04 ft).
- Most feet mined in one month, 1,754.17 m (5,755.15 ft).

Conclusion

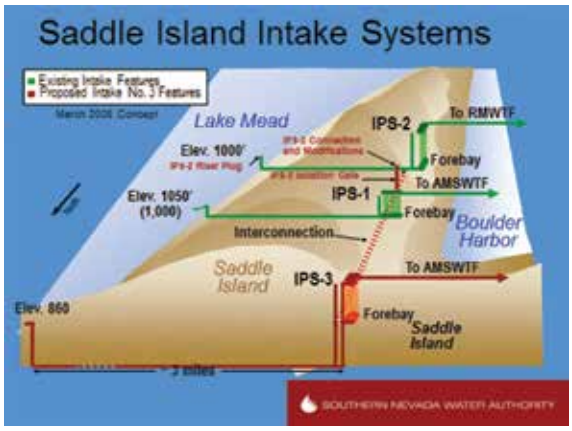
The methods used for this project have been performed countless times over the years. Every project encounters unexperienced situations, but by using proper planning, incorporating new technology with time-tested methods and experienced personnel, S-K JV has been able to able achieve three mining production world records and perform remarkably well at the Indianapolis Deep Rock Tunnel Connector project. ■

FEATURE ARTICLE

Lake Mead intake No. 3: TBM tunneling at high pressure

Figure 1

Project overview.



In response to the severe drought on the Colorado River basin and in order to preserve existing water capacity to the Las Vegas Valley, the Southern Nevada Water Authority contracted a new deep-water intake (Intake No. 3) located in Lake Mead. The current project (Contract No. 070F-01-C1) includes 5 km (3 miles) of tunnel with very difficult geological conditions and a 200-m (650-ft) deep shaft and marine works. This paper will present the current status of the design-build contract being constructed by Vegas Tunnel Constructors and the challenges and problems faced and the innovative solutions developed to handle the difficult conditions encountered during tunneling with up to 15 bars of pressure.

Jim Nickerson, Roberto Bono, Claudio Cimiotti and Erika Moonin

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Project background

The Las Vegas Valley receives the majority of its water from Lake Mead, which is located approximately 30 km (20 miles) east of the Las Vegas, NV metropolitan area. Due to the severe drought that has hit the southwest region of the United States, the water level in Lake Mead has receded from its high water level of 372 m (1,221 ft) above mean sea level (amsl) to a low of 330 m (1,076 ft) amsl in June 2015. Should the lake level continue to fall, at elevation 320 m (1,050 ft) amsl, the current water intakes will not be able to draw enough water to meet the needs of the local area. The risk of losing water capacity has prompted the construction of a new deeper intake. Not only is the new Intake No. 3 situated at a lower elevation in the lake at 262 m (860 ft) amsl, the new Intake No. 3 is also located to draw better quality (Fig. 1).

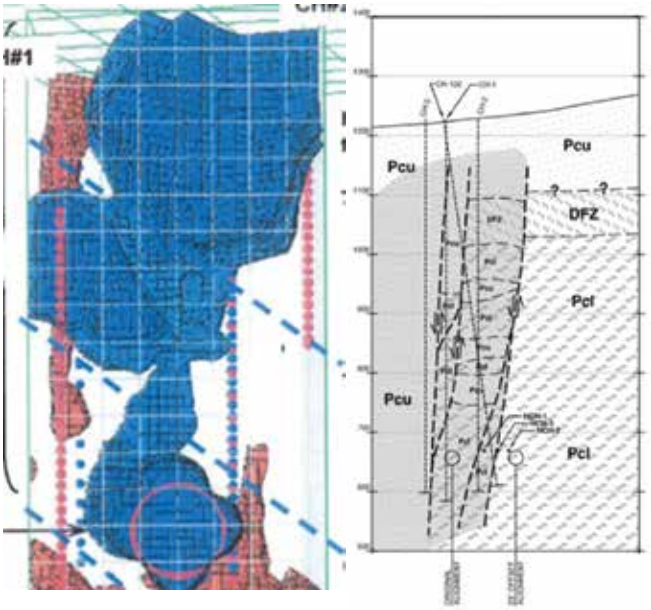
Project challenges

The project has had several difficult challenges to overcome:

- The work consisted of a 1.2 kt (1,300 st) structure constructed on a barge and lowered 100 m (330 ft) into Lake Mead anchored with 9,200 m^3 (12,200 cu yd) of tremie concrete.
- The drill-and-blast starter tunnel was impacted by three inflow events, resulting in a one-year project delay.
- One of the main challenges was selecting the tunnel boring machine (TBM) and excavating the tunnel with expected hydraulic head pressure of as much as 17 bar (16 bar was the highest pressure recorded during the drive), crossing faulted areas, low rock cover and the risk of tunnel instability

Figure 2

Tomography and geological condition.



due to direct connection with the lake.

- Extensive pre-excavation grouting with a constant head pressure ranging from 12 bar to 15 bar.
- Structural repair of the cutterhead in difficult hydrogeological conditions [water inflow of approx. 800 m^3/hr (4,000 gpm)].
- Complete repair of the cascade sealing system for the main bearing and two replacements of the pinion bearings.
- The TBM approach to the intake structure.

Shaft, cavern and starter tunnel

The Intake No. 3 project consists of a concrete-lined shaft that is 183 m (650 ft) deep with an internal diameter of 10 m (30 ft). The shaft intersects a cavern that is 61 m (200 ft) long and was designed to accommodate the assembly of the TBM. The starter tunnel is 120 m (360 ft) long to allow the TBM to start mining in closed mode configuration and to house the belt storage unit when the TBM operates in open mode.

The construction of the shaft started in August 2008 and ended in May 2010. The shaft and cavern were excavated by conventional drill and blast method, 3 m (10 ft) per round and was concrete-lined as the shaft was excavated.

Three extensive grouting campaigns were performed to control the high water inflows encountered during the excavation of the shaft.

Mining work on the original starter tunnel began in February 2010 and, after 47 m (150 ft) of excavation, a large inflow occurred, approximately 5,000 m^3 (6,600 cu yd) of material filled the starter tunnel and the cavern. Drilling equipment for ground investigation was then mobilized to understand the geological conditions and to evaluate the need of grouting from the surface.

After a month of investigation and grouting, the dewatering of the shaft and cavern began. The water was pumped at slow increments to check the condition of the concrete lining and to closely monitor the water inflow coming from the starter tunnel. After the dewatering was completed, work began, which including removing the buried equipment and reestablishing electricity and ventilation.

On Oct. 26, 2010, excavation to reinstate the starter tunnel to its previous face station began. On Oct. 27, while excavating the top bench, there was a second in-rush of material. A bulkhead was installed to contain the flowing material.

Between Oct. 27 and Dec. 31, drilling began on additional core holes on surface and underground to look for an alternate alignment. Concurrent work resumed with drilling drainage and grout holes in the original alignment.

On Dec. 31, a third inflow occurred during the drilling of one of the holes. In January 2011, the decision for a new alignment at 23° east of the original tunnel axis was taken.

The old starter tunnel was abandoned, the new, 120-m (360-ft) long, starter tunnel was excavated by drill-and-blast utilizing a canopy pipe system to ensure the stability of the tunnel. The new starter tunnel was successfully completed at the end of July 2011.

TBM tunnel drive

TBM description. The TBM used to excavate the 4.5 km (3 miles) of the intake tunnel was a Herrenknecht hybrid machine. It was a prototype with the capability of operating either in open or closed mode, depending on the hydrogeological conditions of the rock masses encountered.

Open mode operation consisted of excavating the ground without any face support, evacuating the excavated material via a 18-m (60-ft) long horizontal screw conveyor. This fed a system of belts that ran along the TBM trailing gear, then on a continuous conveyor along the lined tunnel and terminated at the bottom of the shaft where the muck was discharged into two buckets. Each bucket had a capacity of 15 m^3 (20 cu yd) and ran vertically up the 180-m (600-ft) shaft to the surface (Figs. 3a and 3b).

Once on the surface, an overland conveyor was utilized to take the muck to the designated disposal area on the site.

In closed mode the TBM operates like a slurry machine. Mining was performed by applying a support pressure at the face. This mode was used in order to help stabilize the ground and to reduce the risk of tunnel flooding in the case of encountering highly permeable rock masses or direct connection with Lake Mead.

The machine was designed to withstand a maximum hydraulic head pressure of 17 bar and operate at 15 bar. The cutterhead was equipped with 48 cutters, 43 cm (17

in.) in diameter excavating a tunnel diameter of 7.22 m (23.7 ft). The cutterhead required 2,800 kW and the total installed power was 5,750 kW. The breakout torque was 10 MNm and the thrust ranged from 70,000 kN to 100,000 kN.

All of the equipment necessary to operate the TBM was installed on 15 gantries with a total length of 185 m (607 ft) and a total weight of 1.5 kt (1,650 st).

Among many special features, the TBM was equipped to handle high water pressure and inflows. The machine was also equipped with three drill rigs in order to perform either geological investigation (probing and coring) or pre-excavation ground treatment to reduce the permeability and/or increased stability of the rock masses ahead of and around the TBM. Drilling could be carried out through the cutterhead or the shield with a pattern of holes (14 peripheral through the shield; 20 through the cutterhead) characterized by different inclinations (0°, 3.5° and 7°).

Hyperbaric interventions. Face interventions for maintenance occurred in atmospheric conditions. However, in the event maintenance was required during closed mode operation, the TBM was equipped and the personnel was trained for hyperbaric interventions. The equipment to perform saturation dives at high pressure included:

- 1,200 gas cylinders (heliox), stored on site.
- Four tube trailers (135,000 cf each), stored off site.
- Saturation control van.
- Special decompression chamber/medical lock.
- Transport shuttle.

Reach 1: Lower and upper plate formation

Geology STA 4+79 to STA 31+81. The lower plate was characterized by a mix of amphibolite gneiss with presence of quartz-feldspar bedding. In the detachment fault, we encountered soft, highly fractured and brecciated clay gauge material.

The upper plate was characterized by a heterogeneous assemblage of crystalline metamorphic rock: predominantly, quartz-feldspar, granite, pegmatite and mica schist.

Drive. The TBM was launched on Dec. 27, 2011. Based on the expected geological conditions of the Saddle Island

Figure 3a

Open mode configuration.

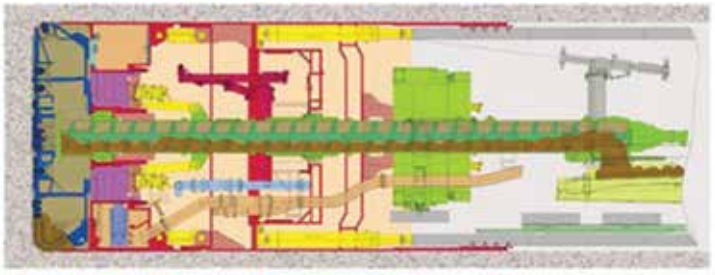


Figure 3b

Closed mode configuration.

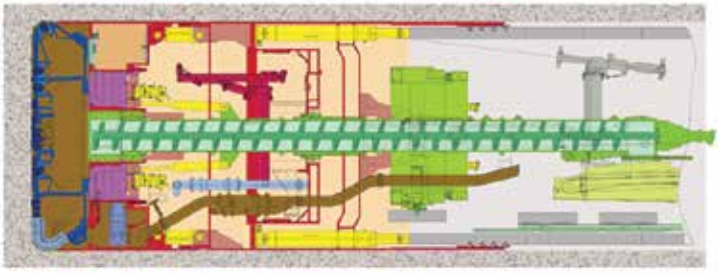


Figure 4

Grouting campaigns – grout patterns.

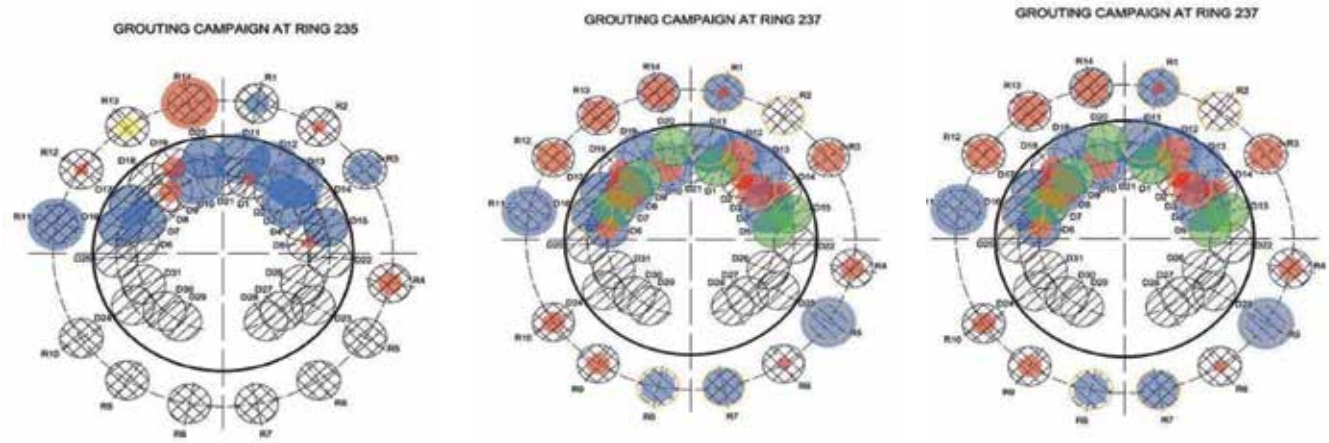


Figure 5

Water inflow 912 m³/h (4,000 gpm) and the cutterhead repair.

Lower Plate, the plan was to mine the first 200 m (600 ft) of the TBM tunnel in closed mode with face support pressure of less than 7 bar.

After 140 m (460 ft) of excavation, at push 77, the air bubble pressure was lowered and maintenance was carried out at atmospheric conditions. There, a subvertical fault entering the tunnel alignment from left to right was detected and mining resumed with pressure at the face adjusted to 12 bar to compensate for the hydraulic head. The TBM progressed very well into the detachment fault and the slurry pressure in the excavation chamber was raised to 13 bar to address the increased ground water head and the nearly cohesionless material being excavated.

On July 2, 2012, at approximately 280 m (920 ft) of excavation, the TBM penetration values became lower. The decision was made to lower the face pressure and inspect the cutterhead.

In order to assess the feasibility of men entering into the working chamber under atmospheric pressure it was important to estimate the quantity of water inflow. For this purpose, the TBM could be used to perform a large-scale piezometric test. The concept was to utilize the slurry line to measure the increase of seepage water by observing the change of water outflow in the slurry line while reducing the bubble pressure in 0.5 bar increments.

In July 2012, three piezometric tests were performed but aborted at 10 bar with more than 200 m³/h (880 gpm) of water inflow.

At this point, an inspection of the cutterhead was only possible by using a camera installed on a steel pipe pushed into the excavation chamber through a drill port equipped with a blowout preventer. The inspection showed that the cutter conditions were not bad, and on Aug. 1, 2012, the TBM resumed mining with face pressure raised to 14 bar.

Figure 6

Cascade sealing system.

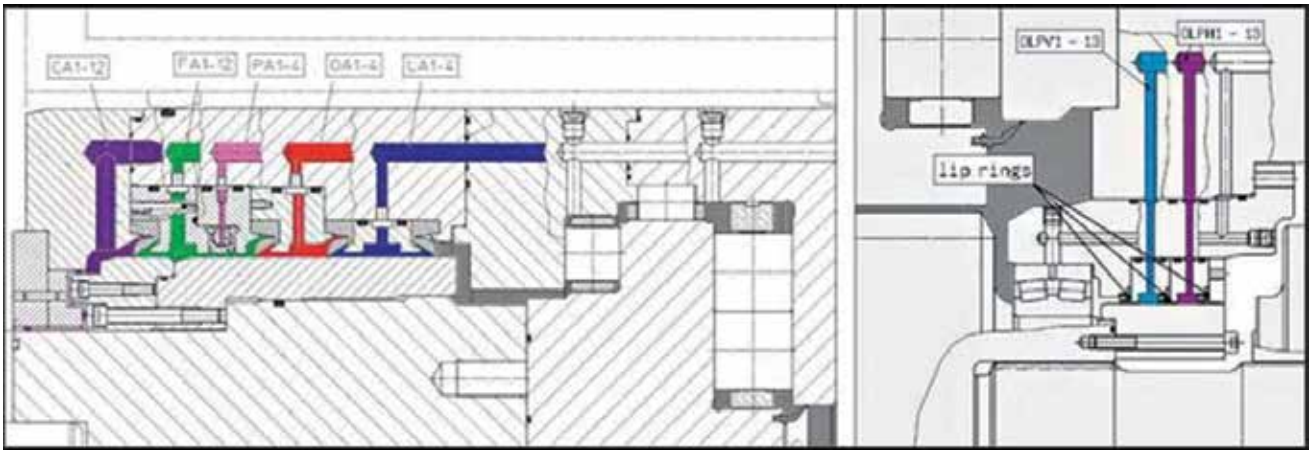


Figure 7

Chamber in front of the cutterhead.

During the next 77 pushes, 10 tests were performed and the resulting water inflows reached a maximum of 1,100 m^3/h (4,825 gpm) at 8 bar face pressure. With that inflow it was impossible to access the excavation chamber for maintenance under atmospheric pressure.

On Sept. 29, 2012, at push 235, the TBM penetration reduced. The camera inspections detected wear on the cutters. The possible scenarios were to either perform a series of pre-excavation grouting campaigns to allow for maintenance or prepare all necessary equipment for hyperbaric intervention in saturation.

Hyperbaric work at 14 bar pressure had more adherent risk, so pre-excavation grouting of the ground ahead and also around the TBM was begun. However, the hyperbaric intervention was still an option and the procurement of the gas equipment, and the logistics was planned concurrently with the grouting program (Nickerson, 2013).

Preexcavation grouting campaigns and cutterhead repair

The ground treatment ahead of the machine was planned and based on the GIN-method, refusal injection pressure and maximum injection volume values were defined in accordance with the fractured ground conditions. A significant difficulty was the fixed pattern of available drilling holes (see green and blue dots in Fig. 4).

The first grouting campaign was carried out at ring 235. The area to be grouted was planned to extend 11 m (36 ft) covering the upper part of the layout shown on Fig. 4. After some drilling and grout injection difficulties, the campaign was completed and the machine moved 4 m (13 ft) forward.

The second campaign was performed at ring 237. The umbrella was increased to 15 m (50 ft) with an overlap of 4 m (13 ft) with the first campaign. After completion of the grouting activities, the machine was moved 6 m (20 ft) forward.

The third campaign was executed at ring 240. The

Figure 8

Damaged pinion bearing and gearbox.

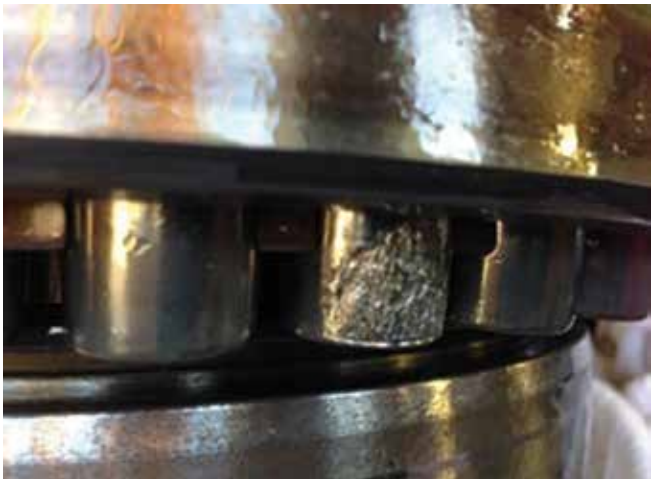
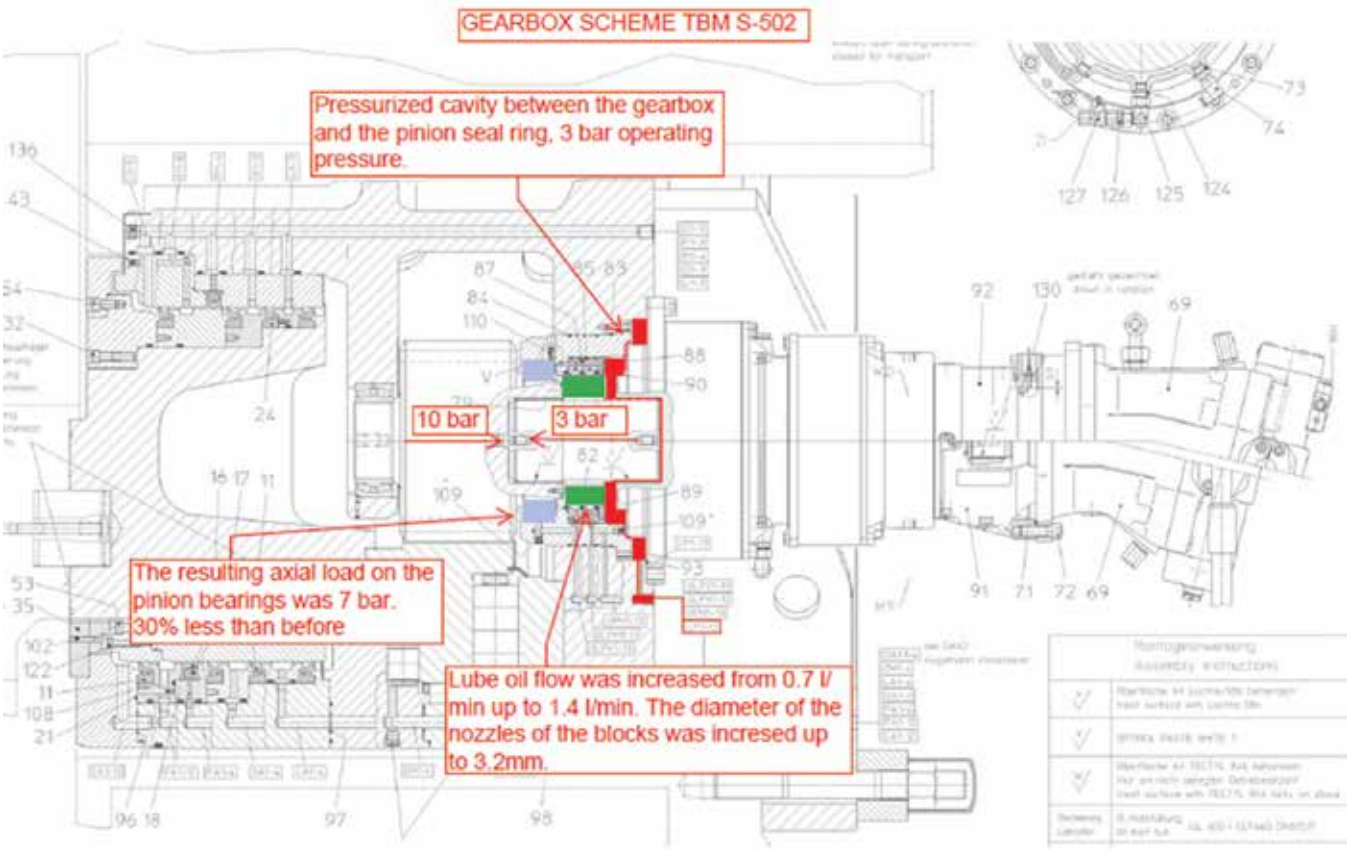


Figure 9

Damaged pinion bearing and gearbox.



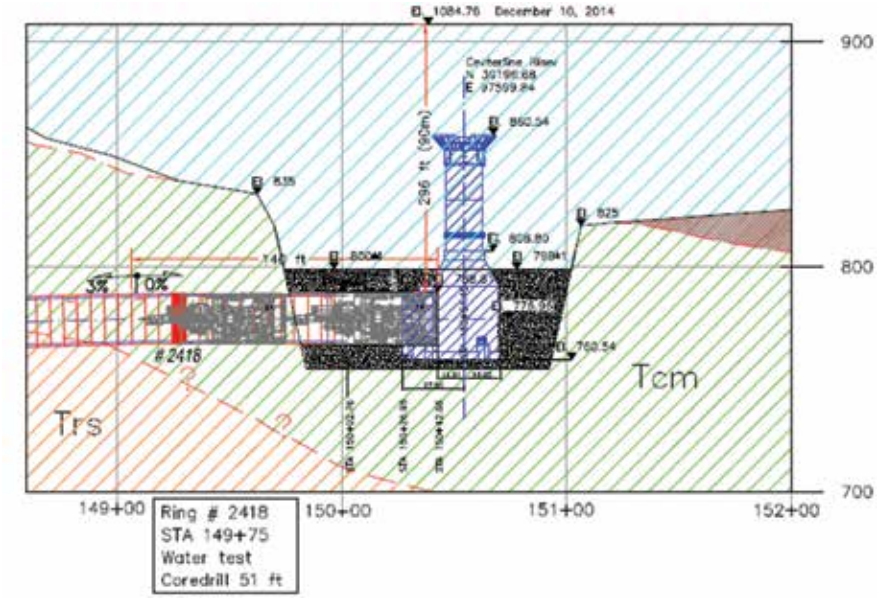
umbrella was further increased to 17 m (57 ft), with 5.5 m (18 ft) overlap with the second campaign. This time, both drilling and grouting were performed in two different stages: up to 9 m (29.5 ft) for the first, and up to 17 m (56 ft) for the second.

After completion of the third campaign, on Feb. 19, 2013 a large-scale piezometric test was performed. At atmospheric pressure, the water inflow was 220 m^3/h (965 gpm) and a face inspection was accomplished. Cutterhead maintenance was started, but stopped due to a local instability of the upper right part of the tunnel face. At that point, because of the low water inflow rate, maintenance of the slurry lines was performed. This included replacement of worn pipelines, valves, pumps and installation of a new hydraulic valve on the slurry return line.

When the slurry circuit maintenance was completed, the TBM advanced forward so that the unstable area was behind the TBM shield. After 9 m (29.5 ft) and then 16 m (53 ft) of advance, piezometric tests were carried out. Water inflow was 880 m^3/h (3,860 gpm) at 2.9 bar and 1,100 m^3/h (4,825 gpm) at 1.9 bar, respectively. The decision to advance forward and find a less permeable location was made, knowing that the machine was leaving the grouted area.

During advance #251 to #253 some steel fragments were found on the magnet at the slurry separation plant. It was decided to stop the TBM from advancing to investigate the problem. On March 25, 2013, a piezometric test was performed. The pressure was successfully lowered to atmospheric and the face inspection showed that the central part of the cutterhead had severe damage to the cutters and the cutter housing. The water inflow was measured to be approximately 912 m^3/h (4,000 gpm) and the rock condition was stable. With the stable conditions at the face maintenance work was started. A niche was excavated 4 m x 3 m x 1 m (13 ft x 10 ft x 3 ft) in front of the cutterhead (Fig. 5) using small hand tools. Once the excavation was completed, the structural repair was performed. The water had to be panned away from the work area and ventilation had to be established for the cutterhead repair. Technicians from the TBM manufacturer were brought to site to oversee the repair. The central section of the TBM had to be repaired completely including the disc cutter housings, structure, wear plates and the cutters (Nickerson, 2013).

Figure 10
Intake approach.



Reach 2: Muddy Creek and Red Sandstone formation

Geology STA 31+81 to STA 149+00. The muddy creek section was characterized by different sedimentary formation. The first part was predominantly siltstone, sandstone and gypsiferous mudstone.

From STA 102+00 to STA 108+50, an intrusion of metamorphic rock, predominantly quartz-feldspar gneiss and mica schist typical of the upper plate was encountered.

However, most of reach 2 was characterized by conglomerated breccia with different levels of cohesion.

Drive. The TBM was operated in open and closed modes through this section depending on the ground conditions encountered.

The first 1,615 m (5,300 ft) of excavation were completed in six months, averaging approximately 14 m/d (45.5 ft/day).

Along this stretch teams experienced muck handling issues with the conveyor belt and clogging of the cutterhead.

In particular, it was observed that the clogging phenomena was restricted only in the areas where the clay content was higher and the TBM was advancing in closed mode applying high pressure at the face (average of 12 bar).

Due to clogging of the cutterhead, closed mode operations resulted generally in lower penetration rates. The reduction of the cutterhead openings partially obstructed the material flowing through the cutterhead.

Consequentially, the muck collected in front of the cutterhead and created a stiff layer that hindered the correct operation of the cutting tools (we had several cases of blocked disc cutters or disc cutters with blown gaskets). So, for the same boring force the achieved penetration was smaller. Moreover, trying to increase the penetration by increasing the boring force would squeeze the material into the gap around the shield, thus developing additional frictional forces on the shield and reducing the effective force available for boring (Anagnostou, 2013).

Cascade system replacement. On Jan. 2, 2014, after push #1309, some lubrication grease (EP2) was found in the leakage chamber P3 (Fig. 6). At that time, the TBM was mining in closed mode at approximately 12.5 bar. Production was stopped and full maintenance of the main drive lubrication system was performed.

The TBM resumed mining until ring #1337 was excavated. At STA 84+85 the machine was stopped due to low impulses of the gear box oil. The gear box and the pinion oil filter were found plugged with EP2 grease.

Herrenknecht technicians were informed and under their supervision, a series of tests were performed. It was found that it was probably one of the four cascade seals that failed allowing the lubrication grease to travel back into the main bearing and the pinions.

On Jan. 30, it was decided to replace the Cascade sealing system. In order to do that, a space between the cutterhead and the main bearing had to be excavated to allow the replacement of the seals.

Due to the length of the TBM (approximately 15 m or 45 ft) and the precast lining already in place, moving the TBM backward was not possible. So a chamber of 7.6 m x 7.6 m x 1.5 m (25 ft x 25 ft x 5 ft) was excavated in front of the machine in order to remove the cutterhead and push it forward (Fig. 7).

The chamber was completed in one week and the cutterhead was removed and pushed forward. The total seal replacement took only one month. It was discovered during this process that the second gasket between the EP2 chamber and the oil chamber P2 was broken allowing the grease to contaminate the main drive.

Production resumed on March 17 and mined through different geology without substantial problem, alternating between open and closed modes (avg. pressure 12.5 bar).

Pinion bearings repair. During push #1680 at STA 100+66, the TBM advance was stopped when metal shavings in the gearbox filters were found.

The lubrication system of the main drive were

inspected and this time it was found that there was metal shavings in the gear box filters.

Over the next few days, further tests were conducted under the supervision of a Herrenknecht technician to isolate the problem, which potentially could have caused damage to the main bearing.

One by one all of the pinion gears were removed and inspected. Five pinion bearings were damaged and were the cause of the metal shavings in the main bearing oil. After inspection of the bull gear and the main bearing showed no signs of wear, and the the replacement of all of the 12 pinion bearings (Fig. 8) proceeded.

After approximately 100 rings from the replacement of the first set of pinion gears, there was a second failure at push #1884, STA 117+69.

A large amount of metal shavings was found in the gearbox filters. The same replacement procedure that was performed during the first pinion gears repair was started.

It was determined the failure of the pinion bearings was directly related to the high cascade pressure on the main bearing seals, which caused an unbalanced ratio axial/radial load acting on the pinion bearings. The solution was to reduce the number of drive motors from 12 to eight in order to increase the torque and to introduce a new pressurized chamber P7 (3 bar) behind the pinion bearing in order to reduce the axial load (Fig. 9).

Reach 3: Intake approach – intake connection

Geology STA 149+00 to STA 150+42. The rock formation was characterized by different flows of vesicular and non-vesicular Tertiary basalt highly fractured and predetermined to be mined in closed mode.

Drive. The intake approach was considered to be the last stretch of the drive where the alignment changed from a 3 percent grade to 0 percent grade for the final 42 m (140 ft). In the final drive, the geology changed from red sandstone to fractured vesicular basalt (Fig. 10). The TBM was operated in closed mode due to the thin cover and the large water inflow encountered.

At station 149+75 a core drill was performed to investigate the transition between the basalt and the tremie concrete including the quality of the tremie concrete and the interface of the intake "soft eye" location.

As expected, the basalt was highly fractured due to the previous blasts of the intake structure. The quality of the tremie concrete was better than expected and the result of the core drill showed a clear joint between the tremie concrete and the intake structure.

Prior to the TBM connection, AUS was mobilized to the site to set up the barges in order to perform the marine work which included:

- Removal of the lid from the intake structure.
- ROV inspection of the condition of the corbel/bulkhead and sealing flange in the interior of the intake riser.

Figure 11

Dec 10, 2014 TBM S-502 breakthrough.

- Inspection with the ROV the final position of the TBM in relationship with the intake structure.
- Setting the bulkhead once the TBM had reached its final position and dewatering the intake structure.

The TBM parameters were adjusted to reduce the rate of advance through the tremie concrete and the fiberglass reinforcement of the soft eye. This procedure reduced potential damage to the intake structure.

The excavating pressure was set at 9.3 bar during the final drive of the TBM into the intake structure, which was the theoretical lake pressure.

The material from the soft eye during the last stage of the excavation was inspected at the separation plant. The concrete previously painted on the intake structure/soft eye/intake was seen at the separation plant indicating the TBM was in the correct location. The TBM then continued to push forward until the shield stopped in line with an annulus steel ring cast in the intake structure.

After the installation of the bulkhead dewatering of the intake chamber began. Once access to the intake structure was balanced, the shunt flow around the TBM shield was measured to be 10 L/min (15 gpm) and there was no water leakage from the intake structure/bulkhead.

The Intake connection was a complete success (Fig. 11), the TBM alignment was within a tolerance of +/- 3 mm.

Conclusion and outlook

The project, for the first time worldwide, advanced a TBM at 15 bar, which required several innovations developed on site. It has been a very technically challenging and demanding project and it would not have been completed without the dedication and commitment of the Salini-Impregilo/Healy and the client Southern Nevada Water Authority working together in a true partnership. (References are available from the authors.) ■

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TUNNEL NAME	OWNER	LOCATION	STATE	TUNNEL USE	LENGTH (FEET)	WIDTH (FEET)	BID YEAR	STATUS
Gateway Tunnel	Amtrak	Newark	NJ	Subway	14,600	24.5	2016	Under study
2nd Ave. Phase 2-4	NYC-MTA	New York	NY	Subway	105,600	20	2015-20	Under study
Water Tunnel #3 bypass tunnel	NYC-DEP	New York	NY	Water	20,000	22	2015	Kiewit - Shea JV awarded
Water Tunnel #3 Stage 3 Kensico	NYC-DEP	New York	NY	Water	84,000	20	2017	Under study
Cross Harbor Freight Tunnel	NYC Reg. Develop. Authority	New York	NY	Highway	25,000	30	2016	Under study
South Conveyance Tunnel	City of Hartford	Hartford	CT	CSO	16,000	26	2015	Bid date 4th Q 2015
Red Line Tunnel - Cooks Lane Tunnel	MD Transit Administration	Baltimore	MD	Subway	14,000	22	2016	Project delayed
Red Line Tunnel - Downtown Tunnel	MD Transit Administration	Baltimore	MD	Subway	36,000	22	2015	Project delayed
Purple Line - Plymouth Tunnel	MD Transit Administration	Baltimore	MD	Subway	1,000	30x40	2015	Bid date 4th Q 2015
Thimble Shoal Parellel Tunnel	Chesapeake Bay Bridge & Tunnel Dist.	Chesapeake	VA	Highway	5,700	45	2016	Under design
Northeast Boundary Tunnel	DC Water and Sewer Authority	Washington	DC	CSO	17,500	23	2018	Under design
ICCS/Dekalb Tunnel	Dekalb County	Decatur	GA	CSO	26,400	25	2016	Under design
Bellwood Tunnel Phase 1 Phase 2	City of Atlanta	Atlanta	GA	Water	6,000 21,000	12 12	2016 2016	Under design Under design
Olentangy Relief Sewer Tunnel	City of Columbus	Columbus	OH	Sewer	58,000	14	2016	Under design
Blacklick Creek San. Interceptor Tunnel	City of Columbus	Columbus	OH	Sewer	24,000	10	2015	Under design
Alum Creek Relief Tunnel Phase 1 Phase 2	City of Columbus	Columbus	OH	Sewer	 30,000 21,000	 18 14	 2016 2017	 Under design Under design
Doan Valley Storage Tunnel	NEORSD	Cleveland	OH	CSO	9,700	17	2017	Under design
Westerly Main Storage Tunnel	NEORSD	Cleveland	OH	CSO	12,300	24	2020	Under design
Shoreline Storage Tunnel	NEORSD	Cleveland	OH	CSO	16,100	21	2021	Under design
Southerly Storage Tunnel	NEORSD	Cleveland	OH	CSO	17,600	23	2024	Under design
Ohio Canal Interceptor Tunnel	City of Akron	Akron	OH	CSO	6,170	27	2015	Bid date 8/13/2015
Continental Rail Gateway	CRG Consortium	Detroit	MI	Rail	10,000	28	2015	Under design
ALCOSAN CSO Program	Allegheny Co. Sanitary Authority	Pittsburgh	PA	CSO	35,000	20	2016	Under design
Lower Pogues Run	Indianapolis DPW	Indianapolis	IN	CSO	9,000	18	2016	Under design
White River Tunnel	Indianapolis DPW	Indianapolis	IN	CSO	28,000	18	2016	Under design

TUNNEL NAME	OWNER	LOCATION	STATE	TUNNEL USE	LENGTH (FEET)	WIDTH (FEET)	BID YEAR	STATUS
Three Rivers Protection/Overflow	City of Fort Wayne	Fort Wayne	IN	CSO	26,400	12	2017	Under design
Albany Park Stormwater Diversion	Metro.Water Reclamation Dist.	Chicago	IL	CSO	5,700	18	2015	Bid date 8/27/2015
St. Louis CSO Expansion	St. Louis MSD	St. Louis	MO	CSO	47,500	30	2014	Under design
KCMO Overflow Control Program	City of Kansas City, MO	Kansas City	MO	CSO	62,000	14	2014	Under design
Mill Creek Peaks Branch Tunnel	City of Dallas	Dallas	TX	CSO	5,500	26	2014	Advertise 4th Q 2015
Downtown Bellevue Tunnel - E330	Sound Transit	Seattle	WA	Transit	2,000	40x30	2015	Bid date 9/23/2015
L.A. Metro Regional Connector	Los Angeles MTA	Los Angeles	CA	Subway	20,000	20	2014	Skanska-Traylor JV Awarded
L.A. Metro Westside Extension Phase 1 Phase 2 Phase 3	Los Angeles MTA	Los Angeles	CA	Subway	 42,000 26,500 26,500	 20 20 20	 2014 2016 2017	Skanska/Traylor, Shea awarded Under design Under design
Speulvada Pass Corridor	Los Angeles MTA	Los Angeles	CA	High/Trans.	55,500	60	2017	Under study
Northeast Interceptor Sewer 2A	LA Dept. of Water and Power	Los Angeles	CA	Sewer	18,500	18	2015	RFQ under way
River Supply Conduit - Unit 7	LA Dept. of Water and Power	Los Angeles	CA	Water	13,500	12	2015	Under design
JWPCP Effluent Outfall Tunnel project	Sanitation Districts of LA	Los Angeles	CA	Sewer	37,000	18	2015	Under design
Freeway 710 Tunnel	CALTRANS	Long Beach	CA	Highway	26,400	38	2016	Under design
BDCP Tunnel #1 BDCP Tunnel # 2	Bay Delta Conservation Plan	Sacramento	CA	Water	26,000 369,600	29 35	2017 2018	Under design Under design
Iowa Hill Pumped Storage Project	Sacramento Muni. Utilities District	Sacramento	CA	Water	3,500	20	2018	Under design
SVRT BART	Santa Clara Valley Trans Authority	San Jose	CA	Subway	22,700	20	2016	Under design/ Delayed
Coxwell Bypass Tunnel program	City of Toronto	Toronto	ON	CSO	35,000	12	2015	Under design
Yonge St. Extension	Toronto Transit Commission	Toronto	ON	Subway	15,000	18	2016	Under study
Scarborough Rapid Transit Extension	Toronto Transit Commission	Toronto	ON	Subway	25,000	18	2017	Under design
CSS - East-West	City of Ottawa	Ottawa	ON	CSO	14,400	10	2015	Under design
CSS - North-South	City of Ottawa	Ottawa	ON	CSO	5,300	10	2015	Under design
Energy East Pipeline	TransCanada	Quebec City	QC	Oil	13,780	16	2015	Under design
Second Narrows Tunnel	City of Vancouver	Vancouver	BC	CSO	3,600	14	2013	Under design
UBC Line project	Trans Link	Vancouver	BC	Subway	12,000	18	2015	Under design
Northern Gateway Clore Tunnel Hoult Tunnel	Enbridge Northern	Kitimat	BC	 Oil Oil	 23,000 23,000	 20 20	 2014 2014	 Under design Under design

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Highlights of the UCA Executive Committee meeting

The Executive Committee of the UCA of SME met during the Rapid Excavation and Tunnelling Conference in New Orleans, LA on June 10, 2015. The board confirmed the new slate of officers for the coming year — **WILLIAM EDGERTON** as past chair, **ARTHUR SILBER** as chair and **MIKE ROACH** as vice chair. Two new members joined the executive committee with terms starting immediately. Red Robinson joined the board as a representative in the engineering category and Tony O'Donnell joined in the contractors category.


EDGERTON


SILBER


ROACH

The committee reviewed the current state of business affairs for the UCA. Among the topics discussed included keeping the current corporate and sustaining membership structures as they are. The group also discussed the George A. Fox Conference, which underperformed slightly because of the snow storm that shut down New York City in January, and the Cutting Edge Conference, being held in Denver, CO this year.

Strategic goals for the division were presented to the executive committee. Those goals are:

- Become the primary resource for underground construction issues and information requests.
- Improve the image of underground construction in the minds of the public, government, owners and key constituencies.
- Improve the effectiveness and efficiency of the underground construction industry.

The committee approved the creation of a new UCA of SME Scholarship Committee chaired by Mike Roach. It includes Erin Clarke, Pam Moran and Greg Hauser. More volunteers will be contacted about joining. The committee's first task is to develop a new application path for tunneling/civil engineering students.

In 2016, students will not have to be UCA of SME members to apply. The executive committee will meet next in conjunction with the George A. Fox Conference in January 2016. ■

Robinson and O'Donnell join UCA Executive Committee

Red Robinson and Tony O'Donnell, members of the UCA Division of SME, joined the UCA Executive Committee at the Rapid Excavation and Tunnelling Conference (RETC) in New Orleans, LA.

ROBERT "RED" ROBINSON, CEG, is director of underground services and senior vice president at Shannon & Wilson Inc. He has more than 40 years of experience on geotechnical assessments and has participated in the design and construction of more than 70 tunnels in the Puget Sound area. These ranged in size from 0.9 m (3 ft) in diameter by 914 m (3,000 ft) long directionally drilled utility lines to the world's largest diameter soft-ground tunnel at 19.5 m (64 ft) ID. for Interstate 90.


ROBINSON

Currently, Robinson is involved with tunnels in California, Oregon, Missouri and Washington. He has published more than 60 technical papers on various aspects of geotechnical exploration, design, construction and construction monitoring for tunneling in soil and rock. He has been on a variety of tunneling industry committees including the Underground Technology Research Committee, the AEG Tunneling Committee and the Rapid Excavation and Tunneling Conference Committee. He has also assisted with a variety of short courses on ground improvement, rehabilitation and instrumentation for trenchless and large diameter tunnels.


O'DONNELL

TONY O'DONNELL is the engineering director with Kiewit's Underground District. He is currently on the startup team for the $707 million Rondout-West Branch bypass tunnel. He received his B.E. in civil

EXECUTIVE COMMITTEE

engineering from University College, Cork, Ireland in 1986 and an M.Eng. in sanitary engineering in 1988. He is a professional engineer registered in Washington, D.C.

O'Donnell began his career in 1988 with Mergentime/Morrison Knudsen on the $60 million Washington Metropolitan Area Transit Authority (WMATA) Navy Yard station and the East Tunnels project. In 1995, he joined Kiewit on the WMATA New Hampshire Ave. tunnels. During the next 10 years, he worked in various roles on a variety of Kiewit underground projects along the Eastern seaboard. From 2005 to 2009, he was part of the successful $425 million Portland East Side Combined Sewer Overflow tunnel project in Portland, OR, working as the engineering manager.

Between project assignments, O'Donnell has overseen the Kiewit Underground District's business development, estimating and engineering efforts for all of its underground and tunnel projects in North America. ■

UCA seeks nominations for the Executive Committee

The UCA Division seeks recommendations and nominations from all UCA members for interested individuals to serve on the UCA Executive Committee for the term 2016 to 2020. Current bylaws call for a 19-person Executive Committee. Membership on the committee consists of three officers, chair, vice chair and past chair, and four directors from each of the following areas: engineers, contractors, owners and suppliers. The UCA Executive Committee seeks a balanced representation from the four areas, but it has the option to have more members in one or more areas and fewer members in others.

If you would like to nominate someone for consideration, forward your recommendation to Spencer Chase (chase@smenet.org) at SME headquarters by Nov. 27, 2015. Please remember that the individual must be a member of the UCA of SME. Staff will compile all nominations for the UCA Nominating Committee's consideration.

A few items are requested to help with the committee's decision.

- Please identify in which of the four areas the individual should be considered for service: engineer, contractor, owner or supplier.
- Provide a brief biography or résumé outlining the person's industry experience and service to UCA and other professional organizations.

Note for past submissions

If you have submitted candidates for consideration in the past three years, please resubmit or send a note to check on the status of your nominee. Traditionally, all nominees are resubmitted for consideration for three consecutive years if they have not been selected for the Executive Committee slate. Your diligence will ensure that all qualified candidates are reviewed. ■

PERSONAL NEWS


HENN

RAY HENN (SME), with 40 years of experience in the tunneling and underground construction industry, has formed his own consulting company, RW Henn LLC, Heavy and Underground Construction Consulting. He plans to focus his service offerings on serving on dispute resolution boards, bid support to contractors, underground grouting, claims evaluation, negotiations and arbitration/litigation support, serving as an expert witness, conducting tunnel inspections and condition surveys, and serving on value engineering teams. He is an adjunct professor in underground construction and tunneling at the Colorado School of Mines.

MATTHEW TIBBUTT is the new senior project manager with Geocomp's consulting division in Massachusetts and will lead the instrumentation and monitoring department at the Boston, MA office. Tibbutt will support the company's key projects, such as the Los Angeles Metro Crenshaw/LAX Corridor as well as local projects for MassDOT and MBTA. He has worked on London's Crossrail Project and the Burj Khalifa in Dubai.


TIBBUTT

Brierley Associates has opened an office in Houston, TX to complement its Austin-based operations. The Houston office is headed by Brierley's newest associate, **NANCY NUTTBROCK**, PE. She has 20 years of experience in tunneling and underground construction, engineering and regulatory knowledge of mining and project management. She has recently served with the state government of Wyoming. ■

UCA SCHOLARSHIPS

UCA scholarships are presented at 2015 RETC

Every year, the Executive Committee of the UCA of SME awards several scholarships to the most qualified candidates who apply for the stipends. In 2015, five awards were made. In addition to the cash awards, travel expenses and free registration to the annual conference are given to the recipients.

Applicants are required to be enrolled in an undergraduate or graduate academic program related to tunneling or underground infrastructure. Hands-on experience in the underground environment is also a plus. The Scholarship Committee of the UCA evaluates all applicants based on categories that include, but are not limited to, the candidates' passion for underground work, their potential for success and academic achievements to date, the strength of the candidates' recommendations from educators or employers, any prior UCA involvement and their financial need as presented in the application.

The UCA Executive Committee and the Scholarship Committee ask all UCA members to promote and disseminate the availability of the scholarship and the application process within their organizations — especially to relatives and friends.

Any prior experience, such as internships or summer jobs in the tunneling or underground industry in the planning, design, construction or operation of tunnels and shafts, is a benefit to the applicant being considered. The applications are available at www.smenet.org/students/grants-scholarships.

UCA Division scholarship winners

The Executive Committee of the UCA of SME presented five scholarships at the UCA luncheon during the Rapid Excavation and Tunneling Conference (RETC) in New Orleans, LA this June. Each scholarship recipient also received full conference registration, airfare, hotel accommodations, the proceedings volume, tickets to conference events and a stipend for other expenses.

LISA MORI is pursuing a Ph.D. in the Department of Mining and Earth Systems Engineering at the Colorado School of Mines. She is the vice president of the UCA Student Chapter at CSM. Mori has worked as a research intern or engineering intern for JCM N125 tunnels in Seattle, WA, Brierley Associates, Denver, CO and IGT Salzburg, Austria. She has an undergraduate degree from the University of Leoben, Austria.

SIMON PRASSETYO is a graduate student pursuing a Ph.D. at the Colorado School of Mines in the Department of Civil and Environmental Engineering. He plans a case study in modeling ground response of the Caldecott Fourth Bore Tunnel in Oakland, CA. He was a summer intern with Freeport-McMoRan at the Henderson Mine in Colorado and with Golder Associates at the Bingham Canyon Mine. He has been active in the UCA student chapter, as a volunteer for the Salvation Army and in his local church. He has an undergraduate degree from the Institut Teknologi Bandung, Indonesia and a master's degree from West Virginia

Art Silber (far left) and William Edgerton (far right) presented UCA Division scholarships to (l-r) Kevin Schaeffer,Yulani Wu, Simon Prassetyo, Lisa Mori and Hamed Zamenian at the 2015 RETC.

UCA SCHOLARSHIPS

University on a Fulbright Scholarship.

KEVIN SCHAEFFER is a graduate student pursing a Ph.D. in the Civil and Environmental Engineering Department at the Colorado School of Mines, where he is also the outreach officer for the UCA of SME Student Chapter. He is a member of the Colorado Association of Geotechnical Engineers and was selected to lead a Young Professionals program for the group. He has interned for Peter Kiewit and Sons at the Black Butte surface coal mine and with Kiewit's underground group at the Devil's Slide Tunnel in California. He received his bachelor's and master's degrees from CSM and was a member of the Civil Engineering Honor Society.

YULANI WU is pursuing a Ph.D. at the Colorado School of Mines in the Department of Civil and Environmental Engineering. She is a member of the UCA of SME Student Chapter. She received an Edna Bailey Sussman internship where she worked on a collaborative project in the Appalachian Mountains involving the U.S. Geological Survey Landslide Hazards Program, CSM and the North Carolina Geological Survey. Wu received her bachelor's and master's degrees from the China University of Geosciences.

HAMED ZAMENIAN is a Ph.D. student in the School of Civil Engineering at Purdue University. He is a graduate teaching assistant in the Environmental Improvement Initiative, Engineering Projects in Community Service program and a graduate research assistant in the Center for Underground Tunneling Education and Research. He has worked in the Waste-to-Energy program at the Lugar Center for Renewable Energy, on the Indy Deep Rock Tunnel project in Indianapolis, IN and in several underground pipeline rehabilitation projects. He holds a bachelor's degree in civil engineering from Shomal University in Iran and a master's degree in construction engineering management technology from Purdue. He has authored or coauthored more than 18 papers and poster presentations and is a lead member of Tau Beta Phi, national engineering honor society. ■

RETC SCHOLARSHIPS AND AWARDS

The Rapid Excavation and Tunneling Conference (RETC) Executive Committee annually awards one or more scholarships to students who wish to develop their skills in the rapid excavation and tunneling field. The committee awarded four scholarships at the June 2015 RETC in New Orleans, LA. Each scholar also received a stipend for expenses to attend the conference.

RETC scholarship winners

ROBERT A. GODINEZ is pursuing a master's degree in civil-geotechnical engineering at the Colorado School of Mines. As an undergraduate at Lamar University, he was project manager for two concrete canoe competitions and president of Chi Epsilon civil engineering honor society. He has worked as an intern for Parsons Brinckerhoff in Los Angeles, CA on the Westside Subway Expansion project, plus six additional geotechnical internships. He is a member of the UCA Student Chapter at CSM and presented a paper at the 2015 RETC.


GODINEZ

KOEN DUINEVELD is an undergraduate student at the University of British Columbia majoring in mining and mineral processing engineering. He is active in intramural sports and is the sports representative from the UBC mining department to the university. He has worked in landscaping and construction and as a math tutor.


DUINEVELD

JOHN M. MEYER is a student and research assistant pursuing a Ph.D. in mining engineering at the Colorado School of Mines. Since 2008, he has worked in his own consulting business mapping geological hazards, landslides and rock falls, analyzing surface water hydrology, trenching studies and soil analysis, generating maps and preparing client reports. Previously, he worked for Quantum Technology Sciences as a geophysicist investigating seismic waves and seismic signal detection to locate miners trapped underground.


MEYER

CHASE CHARRON is a junior studying mining engineering and green engineering at the Virginia Polytechnic Institute and State University. As a member of the Burkhart Mining Society, the SME Student Chapter, he participates in intramural sports, and is also a member of ISEE. Charron was a summer intern at Unimin Corp. in Spruce Pine, NC working with mine waste water problems, blasting layout and processing.


CHARRON

RETC SCHOLARSHIPS AND AWARDS

RETC Attendance Awards

The goals of the RETC student conference scholarship program are to provide students with skills and information for a career in the underground industry and to provide career and networking opportunities.

Applicants for RETC Attendance Awards must be full-time sophomore, junior, senior or graduate students with a designated major in an applicable field of engineering (civil, mechanical, mining, electrical, geological) or construction management.

The 2015 awards paid the travel expenses for seven students who wished to attend the 2015 RETC in New Orleans, LA.

Application forms for RETC scholarships and Attendance Awards can be found on the SME website at www.smenet.org/scholarships.

The 2015 award recipients were:

- Jessica Buckley, Colorado School of Mines.
- Gopi Bylapudi, Southern Illinois University-Carbondale.
- Jacob Grasmick, Colorado School of Mines.
- Caitlyn McKinley, Queens University, Kingston, ON, Canada.
- Dallas Rolnick, University of New Orleans.
- Daniel Rowles, Virginia Tech.
- Rahul Thareja, University of Nevada, Reno. ■

OBITUARIES

JACK J. BURKE

An appreciation by George Yoggy

As common as rock and drilling are to tunnel construction so, for the past 65 years, has Jack Burke been to those in and around the underground industry. From his early days as a young engineer, designing and building equipment to break and move rock, to his later years guiding and supporting engineers and contractors challenged by underground projects, Burke was known to nearly everyone involved in the tunneling business, at home and around the world. His friends are many, and long is the list of those with memories and gratitude for his wisdom, experience, guidance and support.

Mr. Burke, as many refer to him, began learning his craft the old fashioned way. In 1946, following four years of service in the U.S. Navy, he returned to Brooklyn, worked on the New York aqueduct and other projects and completed his engineering degree. He then joined Gardner Denver to learn what tunnel equipment and tunneling was all about. As a field engineer, he quickly became involved with the design and engineering of drilling equipment and how it was used at various projects around New York and New England. His passion for making things work and learning from others, as well as sharing his skills, quickly endeared him to tunnel stiffs and contractors alike.

BURKE

Burke's love for the work and the trust of the men made him a messenger in the realm. To further communicate the progress of projects and the men involved, he began writing the *Hard Rock News* as a means to let people know what was going on. Networking is a modern term for business and industry, but the early tunnel builders relied on the word passed from one tunnel hand to another and for many years *Hard Rock News* was the way to keep in touch. And, of course, his talent for writing and penchant for sharing fostered the infamous "Tunnel Stiffs Tales." He was also a contributing editor to many tunnel industry publications.

Burke continued developing means and methods for improving drilling and benefitting the underground industry throughout his career with Gardner Denver and following with the Sullair Mining Equipment Division. He retired from Gardner Denver in 1988 and continued to consult to the industry for many more years. His support of Jack Lemley and the Channel Tunnel project provided an opportunity to be present at the "holing through" and he became one of the first to walk from England to France on Dec. 1, 1990.

Honors and recognition have been rightly abundant for a man who has given so much to the tunnel industry. Burke has been a member of The Moles since 1962 and was honored as a Life Member in 2012. "For his tireless efforts to improve industry standards and for his generosity in sharing his findings," he was presented with the Golden Beaver Award for Service and Supply in 1992. The American Underground Construction Association, now UCA of SME, presented Burke with the Lifetime Achievement Award in 2005.

Burke was a man born in the 20s, raised in the 30s, served in the 40s, worked, learned and trained in the 50s, shared, grew, mentored and led from the 60s into the 21st century.

On Jan. 14, 2015, industry personnel held a very special celebration dinner in Los Angeles, CA to honor Burke for a lifetime of contributions to the tunnel industry. The attendees were longtime industry colleagues and family members. A special booklet was prepared and presented to him and the guests that highlighted the various lifetime contributions and achievements he made during

OBITUARIES

his career. He was very moved that the industry he so loved would hold such a special dinner to honor him, and he was humbled by the experience. This was an indication of his character. He died July 5, 2015.

Jack, rest in peace knowing that most of what you left behind is still working. Many thanks.■

In memoriam

JAMES McKELVEY

James McKelvey, a respected and internationally recognized tunnel design, construction and risk management expert, died suddenly on July 20, 2015, at the age of 60.


McKELVEY

McKelvey was born in South Africa on Sept. 15, 1954 and earned his bachelor's degree in civil engineering from the University of Natal in 1976. That same year, he joined Murray & Roberts Roads and Earthworks and began work on numerous South African tunneling projects.

He joined Keeve Steyn Inc. in 1980 and, during his more than 20-year career with the company, became recognized as one of the foremost tunneling engineers in South Africa. He led the company's tunneling team and many major projects, such as the Inanda-Wiggins Tunnels and the Midmar Potable Water Tunnel. In 1998, he accepted the position of chief resident engineer on the Matsoku Weir and Diversion Tunnel, followed by the same role on the 32-km (20-mile) long Mohale Tunnel. Both projects were parts of the Lesotho Highlands Water Project, one of the largest water transfer programs ever developed in Africa and recognized as the Project of the Century by the South African Institution of Civil Engineering.

McKelvey joined Black & Veatch in 2002 as a senior member of the company's geo-engineering group. In 2003, he moved to Charleston, SC to lend his talents to a multiphase wastewater tunnel replacement program. As an associate vice president at Black & Veatch, he began the company's Tunneling Center of Excellence in Indianapolis, IN before becoming the tunnel chief engineer in 2013. During his 13-year career at Black & Veatch, he worked on many of the company's large-diameter tunnel and pipeline projects throughout North America. He played key roles on tunneling projects and programs in Indianapolis, IN, Fort Wayne, IN, Louisville, KY, Columbus, OH, Omaha, NE, Las Vegas, NV, Washington, D.C. and Toronto, ON, Canada, in addition to his work in Charleston and many other locations.

McKelvey left a lasting legacy by mentoring many professionals along the way, and he has also left an indelible mark on the industry as a tunneling authority known for practical, insightful solutions to complex design and construction challenges. He served on the Executive Council and the Organizing Committee of the International Tunneling Association, and he represented Black & Veatch as a sustaining member of the Underground Construction Association of SME.

Within the UCA, McKelvey served as a member of the George A. Fox organizing committee. He was a member of the organizing committee for the ITA-AITES World Tunnel Congress 2016 to be held in San Francisco, CA. He also served as a member of the ITA working group on shotcrete, a tutor of the ITA working group on contractual practice, chair of the South African National Council on Tunneling and of the council's working group on shotcrete. He authored numerous papers and chapters of books, including a logistics chapter in *Megaprojects: Challenges and Recommended Practices*.

McKelvey is survived by Jacqui, his wife of 12 years, five children, two grandchildren and a sister. ■

In memoriam

EDWARD CRUZ

Edward Cruz, husband, father, grandfather, entrepreneur, humanitarian and author, died July 14, 2015.

Born in Camarneira, Portugal on March 22, 1941, he emigrated to the United States at age nine, settling in the Ironbound section of Newark, NJ. Cruz later graduated from the Newark College of Engineering and became a professional engineer in 1968. After working alongside his father and brothers for 20 years, Cruz partnered with his best friend and cousin, Evaristo G. Cruz, to found E.E. Cruz and Co. in 1984. During the next quarter century, E.E. Cruz became one of the most respected construction firms in the country, specializing in tunnels, bridges, deep foundations and infrastructure work.

Cruz's accomplishments and contributions to his community and the construction industry are legendary. He was a former president of the National Utility Contractors Association, the General Contractors As-


CRUZ

OBITUARIES

sociation of New York, the Utility and Transportation Contractors Association of New Jersey and The Moles. He was a trustee of the Associated General Contractors of New Jersey and a member of the New Jersey Construction Hall of Fame.

Cruz served as mayor of Holmdel, NJ, helped create the Ironbound Bank and served on the boards of the Richmond County Savings Bank Foundation and Monmouth University. In 2013, he received a Doctor of Science, honoris causa, from New Jersey Institute of Technology.

A few of Cruz's favorite causes included St. John's Church, the Portuguese Heritage Scholarship Foundation, the Lafayette Street School, the Trust For Public Land, and the New Jersey Performing Arts Center in Newark. He was an antique automobile collector and major force behind the Monmouth County Concours d'Elegance, New Jersey's classic motorcar festival benefitting local worthwhile charities.

Cruz is survived by Sharon, his wife of 51 years, four children and 10 grandchildren. ■

NEW MEDIA

Jet Grouting: Technology, Design and Control

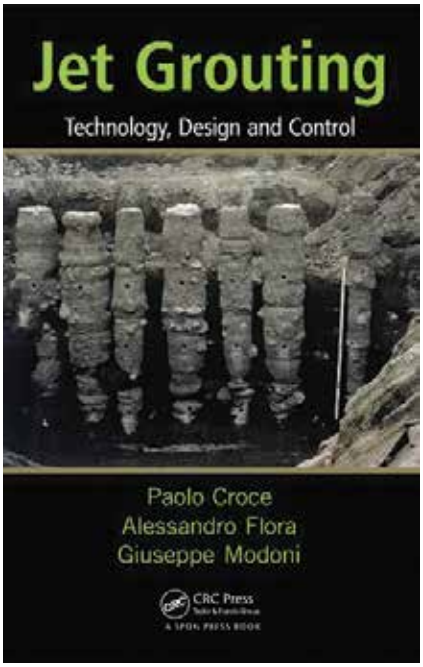
2014 by Paolo Croce, Alessandro Flora, Giuseppe Modoni, published by CRC Press, an imprint of Taylor & Francis, email orders@crcpress.com, www.crcpress.com, hardcover, 302 pp, ISBN 9780415526401, $103.96.

Jet Grouting: Technology, Design and Control analyzes typical jet-grouted structures, such as foundations, earth-retaining walls, water cutoffs, bottom plugs and tunnel supports, and it serves as a practical manual for the correct use of jet grouting technology.

Unlike similar titles providing general information on ground improvement, this book is entirely devoted to the role of jet grouting — its methods and equipment, as well as its applications. It discusses the possible effects of jet grouting on different soils and examines common drawbacks, failures and disadvantages, recent advances, critical reviews and the range of applications, illustrated with relevant case studies.

Jet Grouting addresses technology issues, the interpretation of the mechanisms taking place during the grouting, the quantitative prediction of their effects, the design of jet-grouted structures and the procedures for controlling jet grouting results. It also discusses the design criteria for jet grouting projects and reviews existing design rules and codes of practice of different countries

The book provides practical methods for design calculations of the most important jet-grouted structures, such as provisional tunnel supports, and includes the current standard control methods and most innovative techniques reported for the implementation of quality control and quality assurance procedures. ■



2016 WORLD TUNNEL CONGRESS

San Francisco is host to 2016 WTC

The World Tunnel Congress (WTC) 2016 will be held in San Francisco, CA at the Moscone Center on April 22-28, 2016. Housing and event registration opened in June at www.WTC2016.us.

UCA member companies will be asked to help with the promotion of the conference, which attracts as many as 2,500 attendees from around the world. The conference also offers as much as 3,252 m^2 (35,000 sq ft) of exhibit space.

WTC 2016 is unique in that it will be held in lieu of the UCA's biennial North American Tunneling (NAT) Conference, so the resources, talents and participants of the NAT will now be found at the WTC in San Francisco. Watch for more information at www.wtc2016.us. ■

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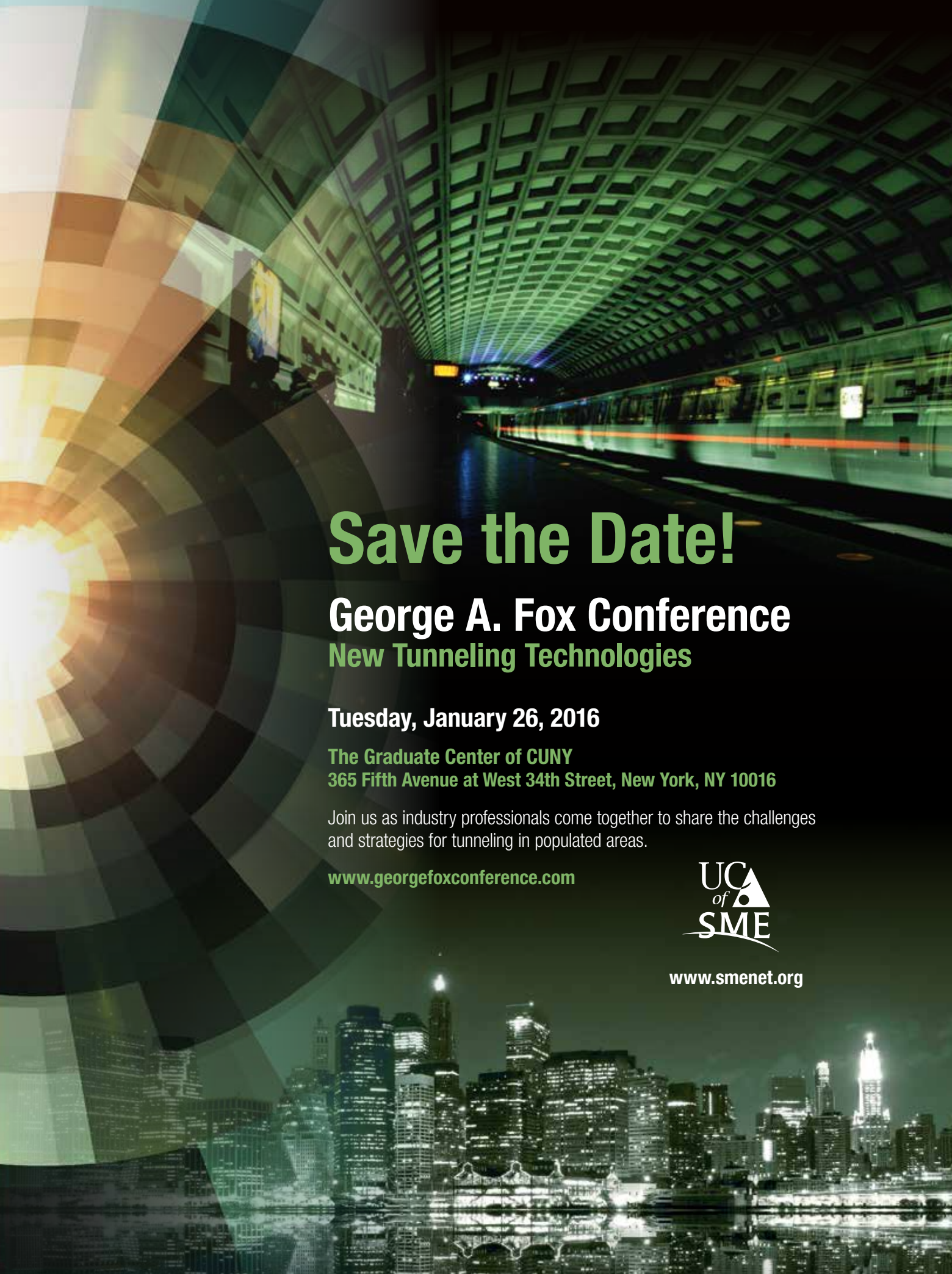

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