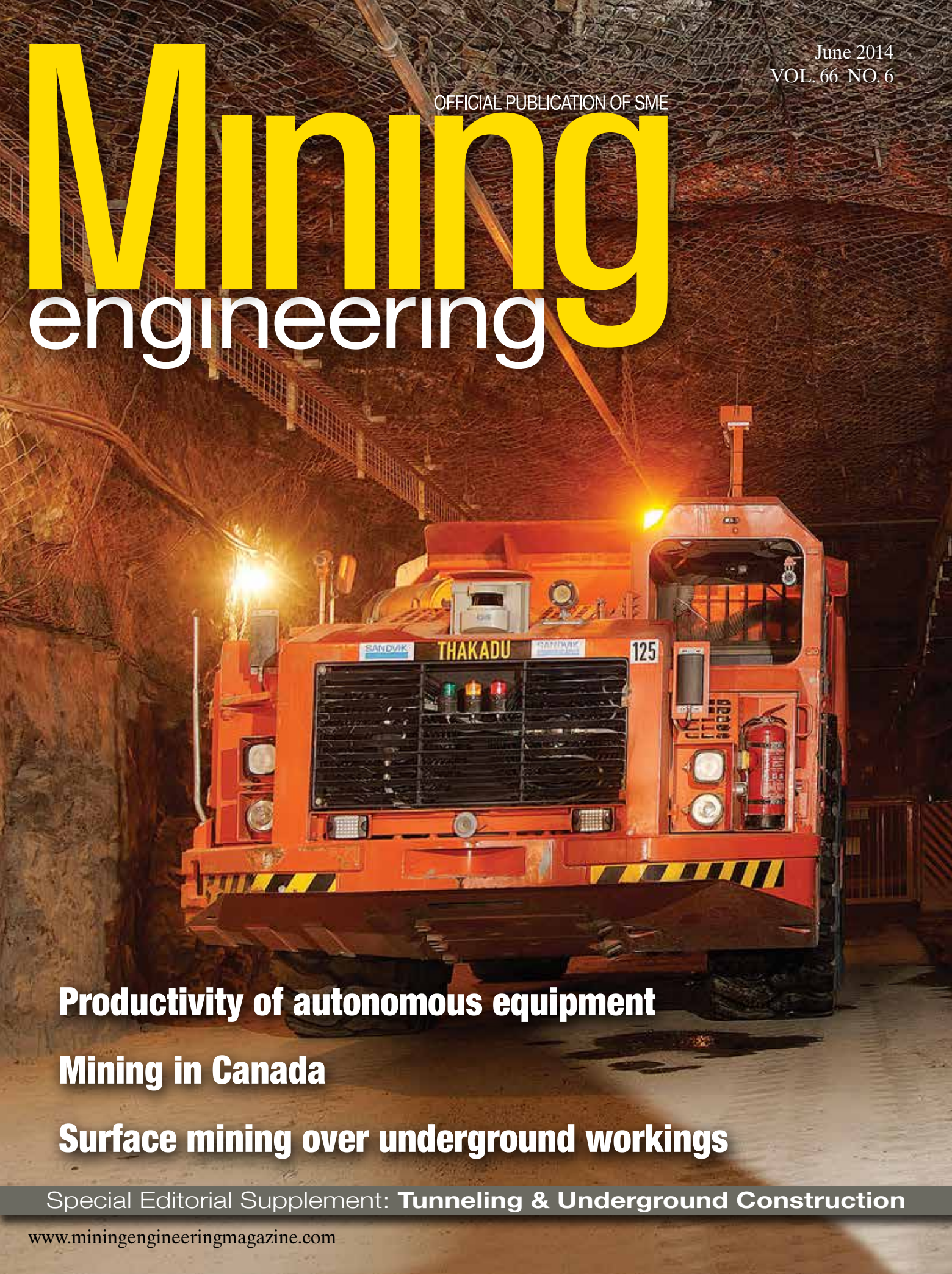
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Surface mining over underground workings

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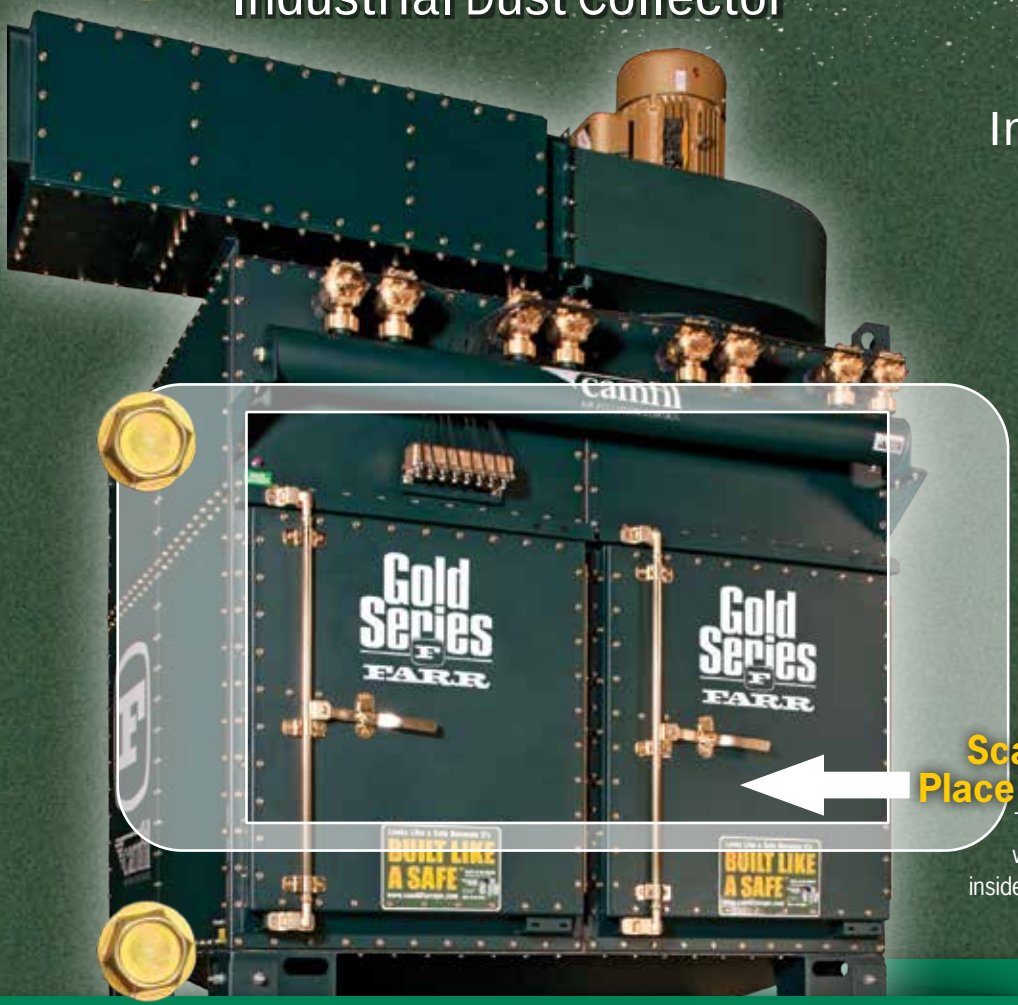
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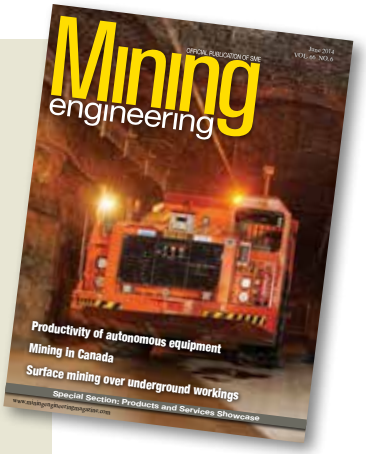
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In This Issue
Mining at Newmont's Phoenix Mine is by surface methods. However, the orebodies targeted were mined previously by underground methods. A discussion of risk mitigation for openpit mining in areas with old underground workings begins on page 44. Maximizing productivity of autonomous loading and hauling machines is examined on page 24. Cover photo shows a Sandvik autonomous LHD at the Finsch Mine. Photo courtesy of Sandvik.

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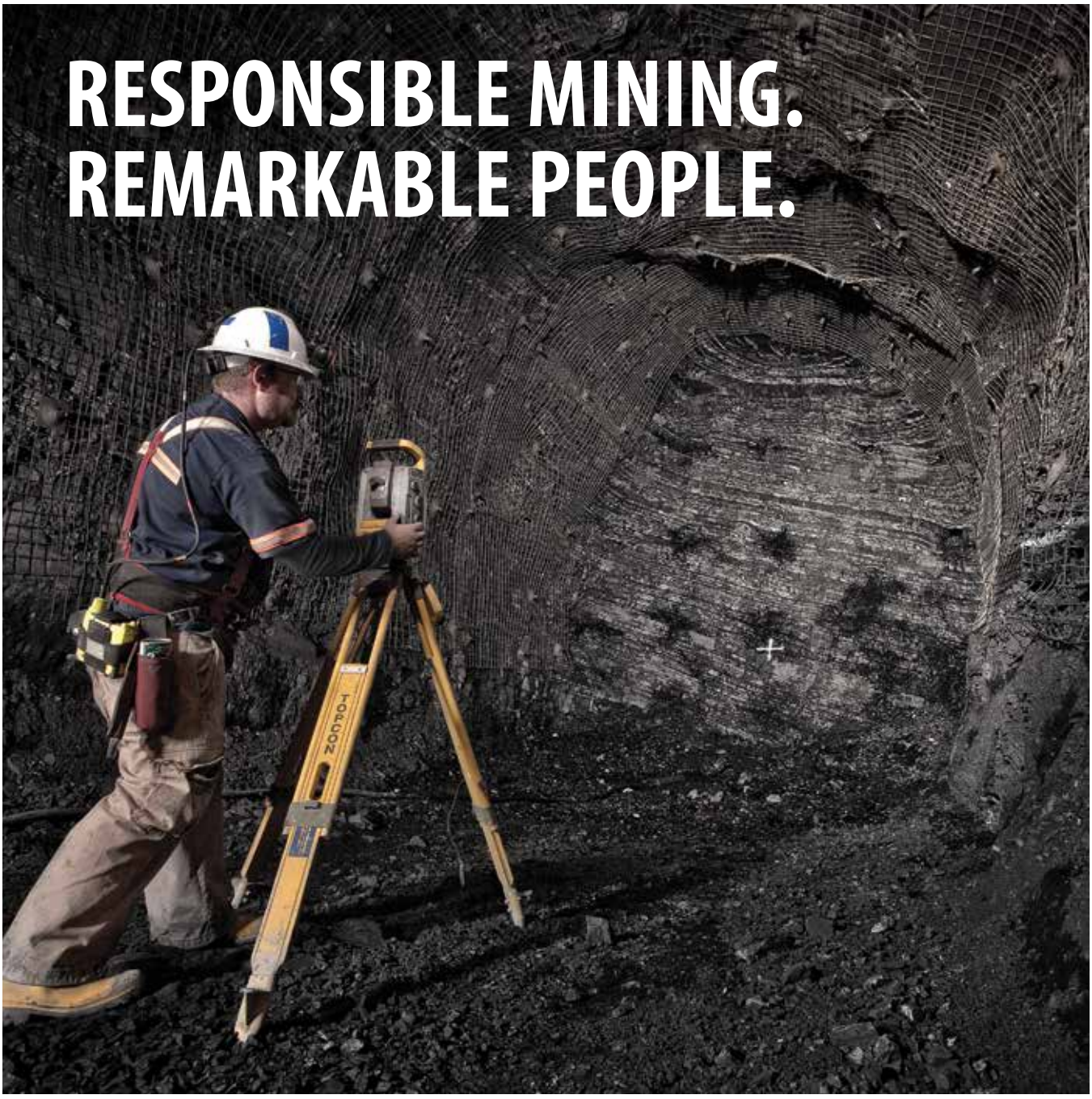
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Global mining industry can learn from the rebound in oil and gas



by John O. Marsden
2014 SME President

In late April, I had the opportunity to participate in the National Academy of Engineering (NAE) Convocation of Professional Engineering Societies that is held annually in Washington, D.C. This meeting was attended by representatives of the majority of engineering societies in the United States, who, in turn, represent more than two million members of the engineering profession. Several key topics were presented and discussed[4], but on the top of the bill was the resurgence of oil and gas based on unconventional resources – an issue of significant importance to the mining industry.

Since 2000, the development of shale oil and shale gas has fundamentally reshaped the U.S. energy industry and has made an impact on the global energy outlook. The production of "tight" oil from shale and other sources has increased from 0.3 million barrels per day (bbl/d) in 2003 to more than 3.5 million bbl/d forecast for 2014. Similarly, shale gas production has increased from under 3 billion cubic feet per day (bcf/d) to about 35 bcf/d during the same time period[1]. Remarkably, the domestic supply of natural gas is forecast to exceed domestic consumption within about two years, and the United States will become a net exporter of natural gas. Some projections estimate that crude oil production could exceed 13 million bbl/d by 2030, with the United States becoming a net exporter of crude oil in that time. This would have been unheard of in 2000, and anyone suggesting this as a possibility would probably have been ridiculed. Recent estimates indicate economically recoverable natural gas resources of 2-4 trillion cu ft in the U.S. (70-140 years of supply) and 15-30 trillion cu ft worldwide (120-240 years of supply)[2].

Whatever your politics, this is good for the mining industry in a number of ways. Natural gas is an important bridge to a long-term energy future that is less reliant on fossil fuels. Being self-sufficient in oil and gas means moderated and more stable energy prices in the near-to-medium term (i.e., to 2030 and beyond). This is important for U.S. metal and mineral production to remain competitive in the global market and to allow development of new resources. Also, more moderate and stable energy pricing, coupled with regional availability of natural gas, is expected to stimulate hubs of U.S. manufacturing capacity and economic growth, which, in turn, will lead to demand for metals and minerals. Additionally, such growth in domestic oil and gas production requires investment in pipelines, refinery operations, gas liquefaction facilities, logistics and other infrastructure.

So, how did this happen? Through technology and entrepreneurial business approaches to resource development. The implementation and adaptation of new technologies for hydrocarbon extraction and processing, the optimization of directional drilling techniques to follow rock strata, enhanced remote sensing and characterization technology and implementation of effective hydraulic fracturing (fracking) techniques have all contributed to this energy renaissance[3].

There are several important lessons and messages here for the mining industry. First, if the United States oil and gas industry can be re-energized and re-invigorated in just 13 years, then so can the mining industry. Second, the development and effective application of new technology can transform a business sector dramatically. All of the technologies employed for unconventional oil and gas resource development were known in the year 2000, but had to be harnessed effectively to reap the benefits. There are many emerging and existing (but immature) technologies that can help to reshape the mining industry – we need to recognize them and embrace them. Third, we have the expertise and the entrepreneurial spirit with in the global mining industry to do this. We have tremendous technical capability and human capacity to accomplish great things – the U.S. oil and gas industry has clearly shown that this can be done to an extent and within timeframes that are nothing short of astonishing. ■

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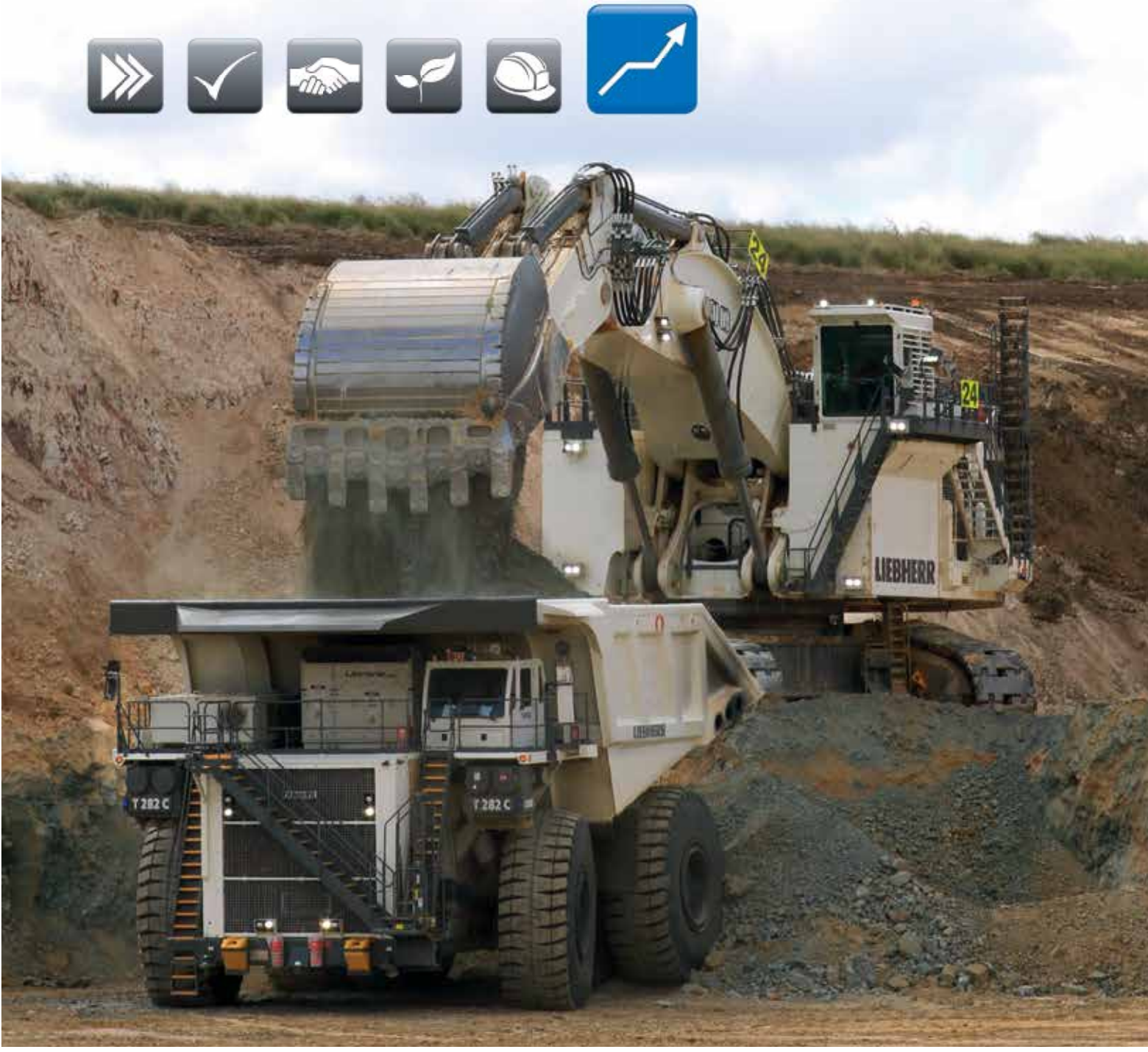
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4 Other topics reviewed included; Innovation in emerging stationary liquid metal battery technology for high capacity energy storage at MIT and Engineering Workforce Trends in the U.S.

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MSHA releases final rule on coal dust standards

REACTION TO THE federal coal dust standard rule that was released by the U.S. Mine Safety and Health Administration (MSHA) on April 23 included a critical response from the National Mining Association (NMA) and the promise to sue from at least one coal mining corporation.

MSHA issued a final rule to lower miners' exposure to respirable coal mine dust in all underground and surface coal mines. The final rule, that will be phased in over a two-year period, reduces the overall dust standard from 2 to 1.5 milligrams per cubic meter of air and cuts in half the standard from 1 to 0.5 for certain mine entries and miners with pneumoconiosis; requires immediate action when dust levels are high; requires more frequent sampling of areas known to have relatively high dust levels; changes the method of averaging dust samples; requires sampling for the full shift a miner works; for MSHA-collected samples, MSHA will issue a citation for any single, full-shift sample at or exceeding the citation level; requires dust samples to be taken when mines are operating at 80 percent of production; and improves medical surveillance of miners.

"Today's announcement represents a lost opportunity to provide better protection for those who need it and more job security for all our coal miners," said NMA president and chief executive officer Hal Quinn in a statement. "We are disappointed that MSHA has chosen to ignore scientific evidence and proven solutions to address exposure to coal dust. The incidence of disease, as documented in the X-ray surveillance data compiled by the National Institute for Occupational Safety and Health, has decreased in most regions and, where it does exist, it is clustered in isolated geographical areas. Rather than follow the evidence with a focused response, MSHA has, unfortunately, decided to proceed with a less effective one-size-fits-all nationwide approach.

"MSHA also declined to embrace constructive suggestions and proven solutions to reduce miner's exposure to respirable coal dust. These include the use of proven personal protection technologies; rotating miners to minimize the duration of exposure to areas of the mine where coal dust is prevalent; and requiring that miners participate in X-ray surveillance programs to encourage prompt medical intervention," Quinn said.

"All of these measures and more have been recommended by NMA and are recognized in other industries to protect workers, yet all were ignored in favor of a standard that experts have concluded cannot be met by existing technologies," he said.

Murray Energy Corp. responded to the release of the rule with an announcement that it intends to sue the U.S. Department of Labor.

MSHA will hold field seminars in coal mining regions to provide a comprehensive review of the new requirements to underground and surface coal operators. Training will be provided to MSHA coal mine safety and health enforcement personnel within five weeks of the promulgation of the final rule. All training materials will be available on MSHA's website at http://www.msha.gov. ■

Tax dispute crippling Zambia mining

A RULE requiring mining companies to provide an import receipt from the country of the final destination for their commodities has resulted in Zambia withholding more than $500 million in tax repayments to companies such as Glencore Xstrata and Vedanta Resources.

Bloomberg reported that the Zambia Revenue Authority last year stopped tax repayments to mines that don't comply with the rule. Mines often don't have access to such documents, as they sell their products to traders and don't know where the copper ends up, said Emmanuel Mutati, president of the industry body.

"They're still withholding the repayments," he told *Bloomberg*. "It's crippling the industry now."

Zambia, Africa's biggest copper producer after the Democratic Republic of Congo, relies on the metal for about 70 percent of its export earnings. The government has accused mining companies of tax avoidance and introduced new rules to tighten monitoring of mines.

The Chamber of Mines made no progress when it discussed the repayments with officials from the Zambia Revenue Authority on April 14, Mutati said. The authority maintains that export certificates are not sufficient for mining companies to claim value-added tax repayments, he said.

"They insist that we should have the necessary papers from the buyers of these metals in the country of final destination," Mutati said. "They're just sticking to that point."

Mining contributes more than a quarter of total government revenue in Zambia, according to the London-based International Council on Mining and Metals. The withholding of VAT repayments threatens to "wipe out profits" as exporters are forced to finance extra capital requirements, it said.

Mining companies in Zambia are also threatened by the 29 percent increase in power costs introduced on April 2, Mutati said. Older, deeper mines, such as those operated by Vedanta and Glencore Xstrata, have fixed pumping and ventilation costs, and the price increase will have a "devastating effect," he said.

Mining companies are still assessing the impact of an increase of about 9 percent in the price of gasoline and diesel, said Mutati. ■



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US Supreme Court rules with EPA;

Agency will be allowed to reinstate cross state air pollution rule

THE U.S. Supreme Court ruled that the U.S. Environmental Protection Agency (EPA) can reinstate limits on power plant pollution that blows across state lines.

The rules were challenged by a coalition of upwind states and industry, which prevailed in lower courts.

Justice Ruth Bader Ginsburg, writing for the majority, said that the EPA must have leeway to confront the "complex challenge" of interstate pollution.

"Most upwind states propel pollutants to more than one downwind state, many downwind states receive pollution from multiple upwind states, and some states qualify as both upwind and downwind," she wrote. "The overlapping and interwoven linkages between upwind and downwind states with which EPA had to contend number in the thousands."

Ginsburg was joined by Chief Justice John G. Roberts Jr. and Justices Anthony M. Kennedy, Stephen G. Breyer, Sonia Sotomayor and Elena Kagan. Justices Antonin Scalia and Clarence Thomas issued a scathing dissent, which Scalia read in part from the bench, and Justice Samuel A. Alito Jr. recused himself from the case.

The regulation stands to affect about 1,000 power plants in the eastern half of the United States that may have to adopt new pollution controls or reduce operations, *The Wall Street Journal* reported. The decision could further threaten the viability of some aging coal plants, which already face other market and regulatory pressures.

The EPA's approach had been challenged by affected states, including Ohio, Michigan and Texas, as well as owners of coal-fired power plants like Southern Co. and Xcel Energy Inc. Those firms argued the EPA overstepped its legal authority and the rules were unfair to plants in upwind states.

"EPA's cost-effective allocation of emission reductions among upwind states, we hold, is a permissible, workable and equitable interpretation" of the Clean Air Act, Justice Bader Ginsburg wrote for the majority.

The ruling comes on the heels of another court victory for EPA air-pollution rules. The U.S. Court of Appeals for the District of Columbia Circuit on April 15 upheld the nation's first-ever national standards requiring power plants to cut emissions of mercury and other hazardous pollution.

The cross-state regulation was the EPA's latest attempt to implement a Clean Air Act provision in which Congress required states to be good neighbors when it comes to air pollution. The EPA rule focused on reducing emissions of nitrogen oxides and sulfur dioxide, both associated with higher rates of heart attacks and respiratory illnesses. The agency said its rule would improve air quality in thousands of counties in the eastern, central and southern U.S.

Justice Scalia signaled strong disagreement with the ruling by reading parts of his dissent from the bench, saying EPA hadn't followed the approach set forth by Congress. "Today's decision feeds the uncontrolled growth of the administrative state at the expense of government by the people," he said.

It is unclear what effect the rule might have on the coal industry.

The National Mining Association, a party to the case, said it is "gravely concerned with the latitude afforded EPA to pre-empt states before they have had a reasonable chance to act." ■

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Merger activity expected to heat up

A NEW STUDY from Ernst & Young suggests it could be a busy year for mergers and acquisitions in the mining and metals industry.

Private equity firms with as much as $20 billion of funds will increase the number of mining deals this year after a steep decline in the first quarter, Ernst & Young said.

In the first quarter of 2014, there were a total of 135 merger and acquisition mining and metals deals worth $6.7 billion globally. This was down 31 percent and 67 percent, respectively, compared with the same quarter the year before, although deal volume was on par with the fourth quarter of last year, Ernst & Young said in its quarterly mergers and acquisitions report.

At the same time, the appetite for mergers and acquisitions is picking up, as evidenced in Ernst & Young's Capital Confidence Barometer survey of more than 1,600 executives, including 128 in the mining and metals sector.

According to the survey, around 60 percent of mining and metals respondents expect global mining and metals deal volumes to improve in the next 12 months, while 53 percent of the mining and metals companies surveyed said they have a pipeline of two or three deals over the next 12 months. ■

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China to appeal rare earths ruling;

World Trade Organization rules China violated global trade rules

THE WORLD Trade Organization (WTO) ruled in March that China had violated global trade rules with its export limits on rare-earth minerals.

On April 17, China said it would appeal the ruling that was considered a win for Europe and the United States in a case involving unfair trade practices.

"China will make the utmost efforts in the appeals process," Ministry of Commerce spokesman Shen Danyang told reporters, *Reuters* reported.

China, which produces more than 90 percent of the world's rare earths, imposed strict rare earth export quotas in 2010, saying it was trying to curtail pollution and preserve resources.

"Regardless of the appeal's outcome, China's policy objectives to protect the environment and natural resources will not change," Shen said. "They will also continue to strengthen management of natural resource products in a manner that accords with WTO rules and safeguards fair competition."

The United States said the export limits allowed China to artificially increase world prices for raw materials crucial for products like hybrid car batteries, wind turbines and energy-efficient lighting, while artificially lowering prices for Chinese producers.

China had been expected to lose the case, after a successful challenge two years ago to its export restraints on a different set of raw materials used in the steel, aluminum, and chemicals industries, including bauxite and magnesium.

In that ruling, a WTO panel said China had failed to demonstrate that its export duties were to curtail pollution or conserve resources. ■



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Peru's Las Bambas copper mine sold;

Chinese consortium buys mine from Glencore for $5.85 billion

A CHINESE consortium purchased the Las Bambas copper mine in Peru from Glencore Xstrata for $5.85 billion *Reuters* reported. It is one of China's largest mining acquisitions in recent years.

Glencore agreed to sell the mine as terms of an agreement with China to allow the merger of Glencore and Xstrata. China placed the demand on its approval of the merger because it feared the combined company would have too much control over the global copper market.

The Chinese consortium is led by MMG Ltd., an offshore arm of China Minmetals Corp. and includes Guoxin International Invest Corp. and China's Citic Metal Co. Ltd.

A Chinese buyer had been considered a virtual certainty since Las Bambas was put on the block, given the deep pockets of China's state-owned enterprises and China's hunger for copper — it is already the world's top consumer of the metal, *Reuters* reported.

Las Bambas, one of the largest mines in Xstrata's project portfolio, is due to begin production in 2015. It is expected to produce more than 450 kt/a (530,000 stpy) of copper in its first five years and 300 kt/a (330,000 stpy) thereafter.

Glencore will receive about $5.85 billion in cash upon completion of the deal. In addition, all capital expenditure and development costs since the beginning of the year until the closure of the deal will also be payable by the consortium.

Capital expenditure and other costs incurred since the start of the year were about $400 million as of March 31.

Glencore said proceeds from the sale will "immediately and materially" deleverage its balance sheet.

The deal, which is expected to close prior to the end of the third quarter, is subject to approval from China's Ministry of Commerce as well as approval from MMG's shareholders.

China Minmetals Non-Ferrous Metals Co Ltd, which holds about 74 percent of MMG, has agreed to vote in favor of the deal, Glencore said.

Glencore said it would continue to look for opportunities to reinvest capital and any surplus capital would be returned to shareholders. ■

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Water reclamation plant to be expanded;

Anglo American plans to double the size of its plant in South Africa

ANGLO AMERICAN'S Emalahleni water reclamation plant, 120 km(75 miles) east of Johannesburg, South Africa, has successfully transformed waste water from the company's coal mines into drinking water for 80,000 people.

The treatment center provides as much as 12 percent of the area's municipal drinking supply and has been so successful that Anglo American is going to double the size of the plant. BHP Billiton and Glencore Xstrata are looking to replicate it at their own sites.

The $130-million plant serves as a template for how the industry could treat waste in the future. It also shows how companies and municipalities are finding new ways to confront an increasingly water-stressed planet, *Bloomberg* reported.

Mines often treat waste water to some extent. Yet, until the Emalahleni water reclamation plant, none was of drinking quality. This plant "is a model," said Marius Keet, acting head of the Department of Water Affairs in the Gauteng region. "It's a very good example of how it should be done."

The 30 million L/d (7.9 million gpd) reverse-osmosis plant recovers 99.5 percent of the mine's waste water, which will increase to 100 percent after the expansion is completed this year. Seawater desalination plants in comparison have recovery rates of 60 percent to 70 percent, said Thubendran Naidu, hydrology manager at Anglo's Emalahleni plant.

While Anglo has no immediate plans to build similar plants in its thermal coal business, it's considering water treatment operations in its platinum and copper businesses, according to Richard Garner, Anglo's water manager. The company is the seventh-largest producer of copper and the largest platinum producer.

Glencore is building a water treatment plant with BHP in the Middelburg coal-mining area east of Anglo's to improve the mine waste water to an approved level so it can flow into waterways. The plant will be commissioned later this year with a capacity of 20 million L of water a day, Glencore said. BHP said it's investing in the Middelburg water plant. ■

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First quarter fatality data released;
MSHA reports a spike in metal and nonmetal operations

THE U.S. Department of Labor's Mine Safety and Health Administration (MSHA) released a summary of U.S. mining deaths that occurred during the first quarter of 2014. From Jan. 1 to March 31, eight miners died in accidents in the U.S. mining industry. Three were killed in coal mining accidents and five in metal and nonmetal mining accidents. The previous quarter was marked by 15 deaths and an increase in the metal and nonmetal sector.

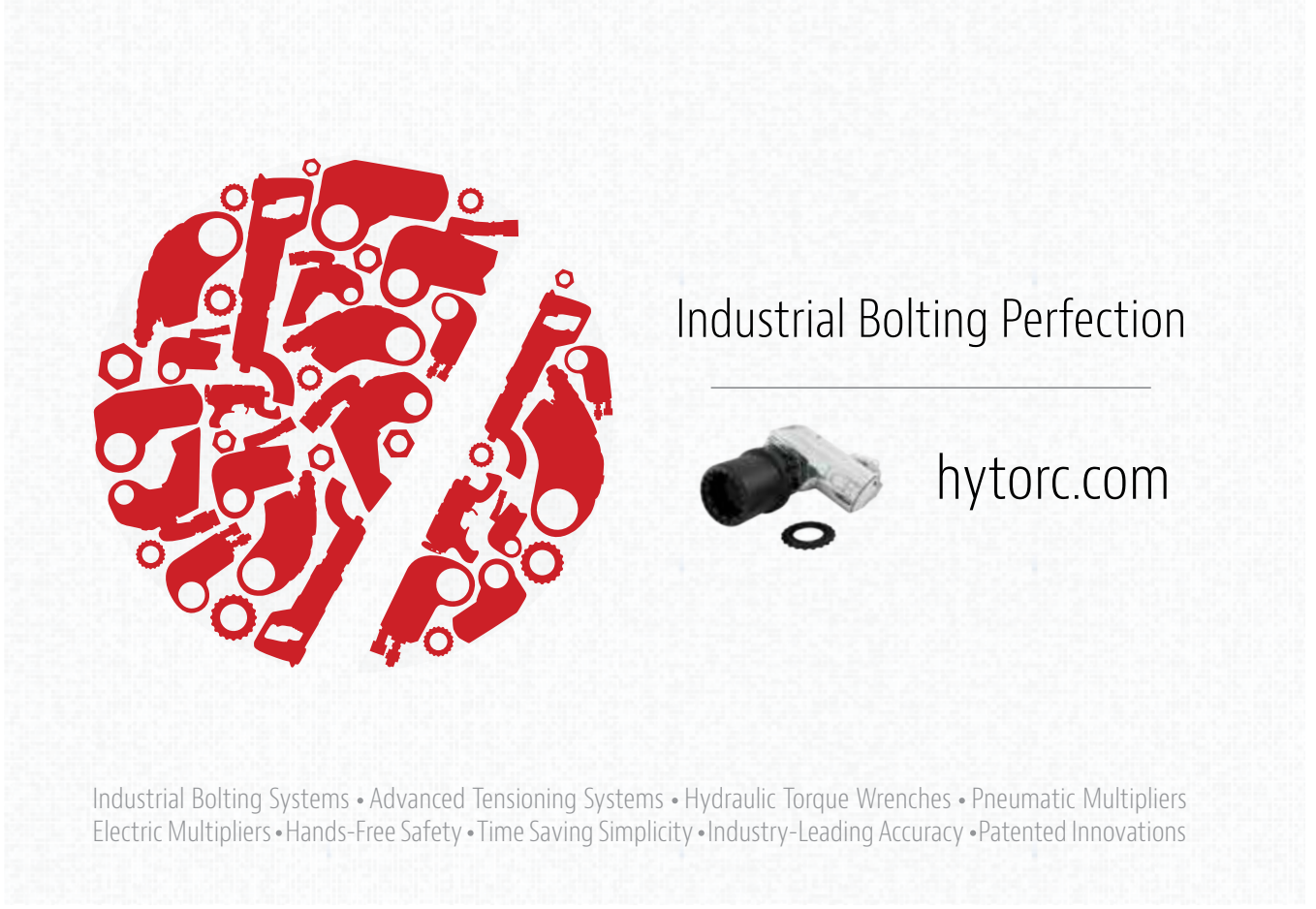
"We have seen a spike in deaths in the second quarter of 2014 as well, primarily in metal and nonmetal mining, which has experienced 19 fatalities since last October," said Joseph A. Main, assistant secretary of labor for mine safety and health in a statement. "MSHA takes this increase very seriously and has called a summit of the key metal and nonmetal stakeholders to identify the problem and take actions to reverse it."

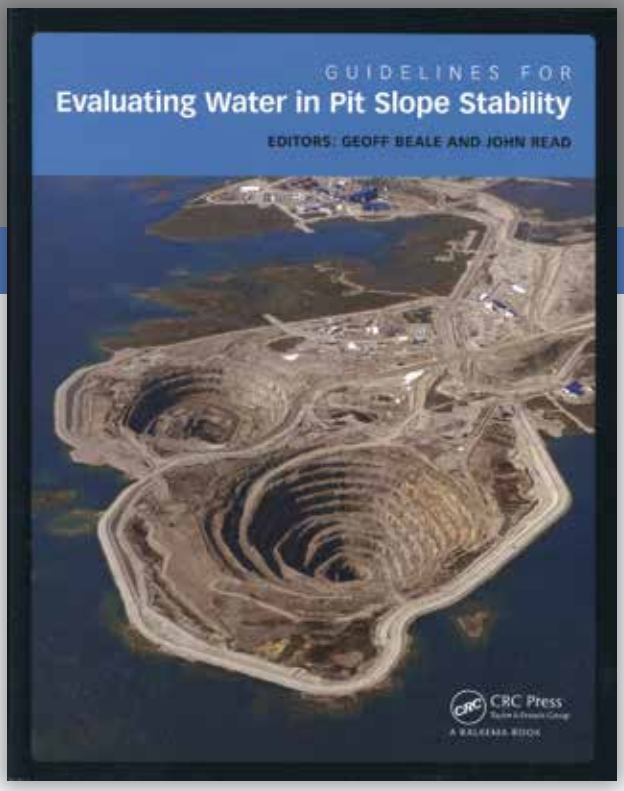
During the first quarter of 2014 in metal and nonmetal mining, two miners were killed by falling/sliding materials.

In coal mining, two miners were killed in machinery accidents. During a special summit with stakeholders, MSHA provided more detailed information on the 19 deaths at metal and nonmetal mines since 2013. The deaths have occurred at crushed stone, sand and gravel, silver, cement, lime, gold, granite, clay and iron ore mining operations in 12 states. Six deaths occurred at underground mines and 13 at surface mines.

"Mine operators need to reevaluate the quality of the training miners are receiving and their examinations of miners' work places because they appear to be lacking," said Main. "MSHA will be paying close attention to these deficiencies, as well as the types of hazards and conditions that have led to these deaths, during mine inspections."

Details on the mining deaths presented at the special summit can be found at MSHA's website www.msha.gov. ■





Guidelines for Evaluating Water in Pit Slope Stability

Edited by Geoff Beale and John Read

A comprehensive look at the hydrogeological procedures needed when performing open pit slope stability design studies.

Guidelines for Evaluating Water in Pit Slope Stability offers slope design practitioners a road map that will help them decide how to investigate and treat water pressures in pit slopes. It provides guidance and essential information for mining and civil engineers, geotechnical engineers, engineering geologists, and hydrogeologists involved in the investigation, design, and construction of stable rock slopes.

The book contains six sections that outline the latest technology and best practices for hydrogeological investigations. The sections cover the framework used to assess the effect of water in slope stability; how water pressures are measured and tested in the field; how a conceptual hydrogeological model is prepared; how water pressures are modelled numerically; how slope depressurization systems are implemented; and how the performance of a slope depressurization program is monitored and reconciled with the design.

Contents

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- Site Characterization
- Preparing a Conceptual Hydrogeological Model
- Numerical Model
- Implementation of Slope Depressurization Systems
- Monitoring and Design Reconciliation
- Hydrogeological Background to Pit Slope Depressurization
- Guidelines for Field Data Collection and Interpretation
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SME
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Alaskan REE project gets legislative win;

State passes bill that clears the way for funding for project

UCORE RARE Metals moved closer to startup of its flagship Bokan-Dotson Ridge rare-earth element project when Alaska's state Senate unanimously passed Senate Bill 99 (SB-99) that clears the way for the Alaska Industrial Development and Export Authority (AIDEA) to issue up to $145 million in bonds to help fund the project.

SB 99 was introduced by Sen. Lesil McGuire (AK-R). Sen. Bert Stedman (AK-R) proposed the amendment, which would authorize the AIDEA to issue bonds to finance the infrastructure and construction costs of the Bokan-Dotson Ridge rare earth element project up to a principal amount of $145 million, subject to its own internal due diligence and board approval. SB-99 was presented to the House by Rep. Feige (AK-R).

"I am thrilled to have been able to take the next step toward realizing Alaska's potential for rare-earth minerals mining," said Alaska state Sen. Lesil McGuire (R- Anchorage). "I have long seen the need for a U.S. source of these important materials and the potential benefit for Southeast Alaska and our state economy. Senate Bill 99 offers Ucore the chance to partner with AIDEA and make this tremendous project a reality."

"We're very pleased with the outstanding support that the Bokan project has received from the Alaska state legislature," said Jim McKenzie, president and chief executive officer of Ucore. "Alaska has a very long history of advancing and supporting key resource projects, both financially and otherwise, and Bokan is no exception. Alaska legislators have recognized that the area has the potential to be America's leading heavy rare-earth production hub, with an array of ancillary industries, such as REE separation and metal manufacture. Our very sincere thanks to Sens. McGuire and Stedman for their vision and leadership in this area, and the collateral support of its co-sponsors."

The bond financing will be subject to AIDEA's internal due diligence and board approval, to be completed subsequent to the release of the Bokan-Dotson Ridge feasibility study on the project. ■





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Please direct course content questions to Dr. Ramani at **rvr@psu.edu.**

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- To ensure availability and quoted rates, reservations must be received by August 14, 2014.
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Letter to the editor;
Comments on February President's Page

Editor,

SME PRESIDENT John Marsden addressed the need for graduate "core' degree programs in the mining industry, indicating they are "in jeopardy." SME encompasses those fields he discussed but also includes "exploration," and the discovery of new resources, something not addressed in his article.

Viable economic geology programs in the United States have declined even more than the mining and metallurgical/mineral process engineering programs due to many of the same factors President Marsden cited (i.e. lack of financial support, no replacement for retiring economic geology faculty, mergers into colleges that lack strong support for exploration-oriented teaching/research).

Ore deposit discoveries will only come from university programs and their students in which graduate economic geology education and research are strong; "graying" of the practicing economic geologists, with retirement in the near future, requires strong support of the viable programs to train the needed young geologists entering the mine geology-mineral exploration field. Replacement of economic geology faculty will best be accomplished by funding geologists who have the mine/exploration experience to obtain a Ph.D. University programs that include economic geology, exploration geochemistry and exploration geophysics teaching/research are essential. The support for continuing economic geology programs will have to come from SME and the Society of Economic Geologists Foundations and the mining industry as federal and states support is lacking.

Tommy B. Thompson
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Maximization of productivity of autonomous equipment in underground mines

by J. Paraszczak

Underground metal mining involves many challenges. Economic slowdown, tough international competition and sometimes volatile metal prices put constant pressure on mine operators to increase productivity and to reduce production cost. At the same time, countries such as Canada, the United States and Australia are experiencing skilled labor shortages that might even stall development of certain mine projects.

Figure 1

An operator at the El Teniente Mine in Chile. Photo courtesy of Sandvik Mining.



Furthermore, some stages of underground production take place in particularly hazardous environments where the safety and health of miners is at risk. Automation of some processes in underground mining is one of the promising avenues to alleviate some of these problems.

Loading and haulage are among the most critical operations and areas where implementation of autonomous vehicles has been targeted. However, although health and safety issues are a primary driver to opt for automation, the latter should ensure an acceptable level of productivity and profitability. With this in mind, this article focuses on the factors affecting operational effectiveness of autonomous underground loading and haulage equipment and the means to maximize it.

J. Paraszczak, member SME, is professor, Universite Laval, Quebec, Canada, email jacek.paraszczak@gmn.ulaval.ca.

Context of loading and haulage equipment automation

There are many reasons to implement autonomous equipment in underground metal mines, with safety of workers being a primary driver and concern. Loading and haulage (LHD) operations particularly involve several risks. In order to fill an LHD bucket safely at a drawpoint and avoid a risk of being buried by falling muck, operators often have to get off their machines and perform this action remotely, usually in the line of sight. Such procedures slow down a loading process and negatively affects productivity. Subsequently, LHD and truck operators are exposed to diesel engine exhaust gases, whose concentrations are much higher than in surface applications and may even lead to lung cancer. Moreover, drivers are also exposed to substantial noise and vibration levels, high-pressure fluid injection, struck by and crushing injuries, as well as slips, trips and falls. These and other hazards may be avoided by moving operators away from the machines.

Concerning productivity, in most mines a considerable amount of working time is lost at shift changes (due to travelling time between workplaces and surface) and due to regulatory breaks. Such substantial reduction of actual working time has an adverse effect on productivity. Another point is equipment reliability and its operational cost. Some operators tend to abuse the machines (wrong gear selection, excessive speed, overloading, collisions with drift walls and other objects, excessive tire slippage, etc.). Such behavior has a negative impact on reliability and availability of the machines and their operation cost. Furthermore, as efficiency of equipment operators may vary considerably during shifts (for example, an effect of operator's fatigue close to the end of the shift), automation is expected to reduce operational variance and assure more production consistency (Lever, 2011).

In this context, automation of LHD equipment is an attractive option to eliminate or at least alleviate some of these problems.

Its no wonder that a lot of research and development work has been devoted to these issues and many attempts to test and implement new technologies have taken place in the last 30 years. The 21st century has brought substantial technological progress and commercialization of some systems enabling autonomous operation of LHDs and trucks. To date, three autonomous



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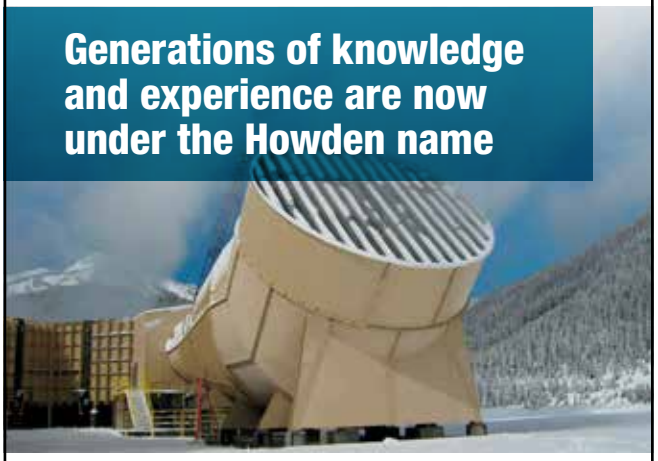


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loading and haulage systems have become commercially available:

- Automine from Sandvik.
- Minegem (Caterpillar).
- Scooptram Automation (Atlas Copco).

Within all these systems, the machines perform many elements of their working cycles without human intervention. For example, LHD machines can tram and dump their buckets autonomously, whereas bucket filling is done remotely by an operator sitting in a control room on surface or in a mobile operating station (Fig. 1). Since 2004, partly autonomous LHDs operating under Automine have been implemented in several mines in Chile, Finland, Australia, Sweden and Kazakhstan (Gustafson, 2011; Goodbody, 2012). Autonomous trucks have been in operation in the Williams Mine in Canada, whereas the Finsch Mine[1] in South Africa has become the first mine where both autonomous trucks and LHDs worked together in the same dedicated production area (Burger, 2006; Chadwick, 2008; Cook et al., 2008) (Fig. 2). Minegem has been introduced mostly in Australia, but also in Indonesia and in Sweden (Caterpillar, 2008; Chadwick, 2010, Gustafson, 2011). Atlas Copco's autonomous ST-14 loader was first used in the Kemi chromite mine in northern Finland and, subsequently, three ST-14s have been shipped to the Diavik diamond mine in Canada and one to El Teniente Mine in Chile (Chadwick, 2010; Gustafson, 2011).

The fact that some of these systems have been operational for almost 10 years proves that loading and haulage equipment automation may be beneficial for mine operators in various countries. However, automation usually incites high hopes (sometimes excessive), but its implementation does not guarantee that the system will achieve better productivity and effectiveness than that with conventional machines. A review of past experience with LHD automation in several mines all over the world done by Gustafson (2011) indicates that numerous attempts have fallen short of the expected objectives and have been aborted. In the sections that follow, the issues of getting the most from autonomous loading and haulage equipment will be reviewed.

Factors affecting operational effectivness of autonomous loading and haulage equipment

A totally effective autonomous machine would run all the time at its maximum or standard production rate. In reality, however, different problems occurring to equipment, its supporting infrastructure or those related to its working environment may cause substantial losses of productivity. What a piece of equipment or system actually delivers in terms of revenue-generating work (achieved capacity or actual production) compared to ideal performance is called operational effectiveness (OE). The latter is a product of availability, utilization rate and production efficiency.

[1] De Beers's Finsch diamond mine uses a block caving method, making it similar to metal mining operations.



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Figure 2

An autonomous truck operating in the Finsch Mine in South Africa.



Availability. Availability (A) is the ability of an item to perform a required function under given conditions at a given period of time or over a given time interval, assuming that the required external resources are provided. A piece of equipment or an entire system may be either in an up state, when it can accomplish useful work for which it has been designed, or in a down state, or "down" when it fails to provide or perform its primary function. The term "uptime" is used to refer to periods when a piece of equipment or system is available. Availability is defined by the following equation:

$$A = \frac{\text{uptime}}{\text{total hours}} * 100\% \qquad (1)$$

Availability depends on the combined aspects of reliability performance, maintenance performance and maintenance support performance (CAN/CSA, 1997).

Utilization. Even if a piece of equipment is in an up state, it does not mean that it does revenue-generating work. Within its uptime, a piece of equipment may operate, be idle or be externally disabled. The latter term depicts the state when an item lacks required external resources, or is disabled due to planned action other than maintenance (CAN/CSA, 1997). Utilization, called

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sometimes "use of availability," is defined as a ratio of actual equipment operating time to its uptime. In this sense, utilization rate (U) is defined as follows:

$$U = \frac{\text{uptime-standby/idle}}{\text{uptime}} * 100\% \quad (2)$$

Production efficiency. Production efficiency may be defined as follows (adopted from Campbell and Jardine, 2001):

$$E = \frac{\text{actual achieved capacity}}{(\text{uptime-standby/idle}) * \text{rated capacity}} * 100\% \quad (3)$$

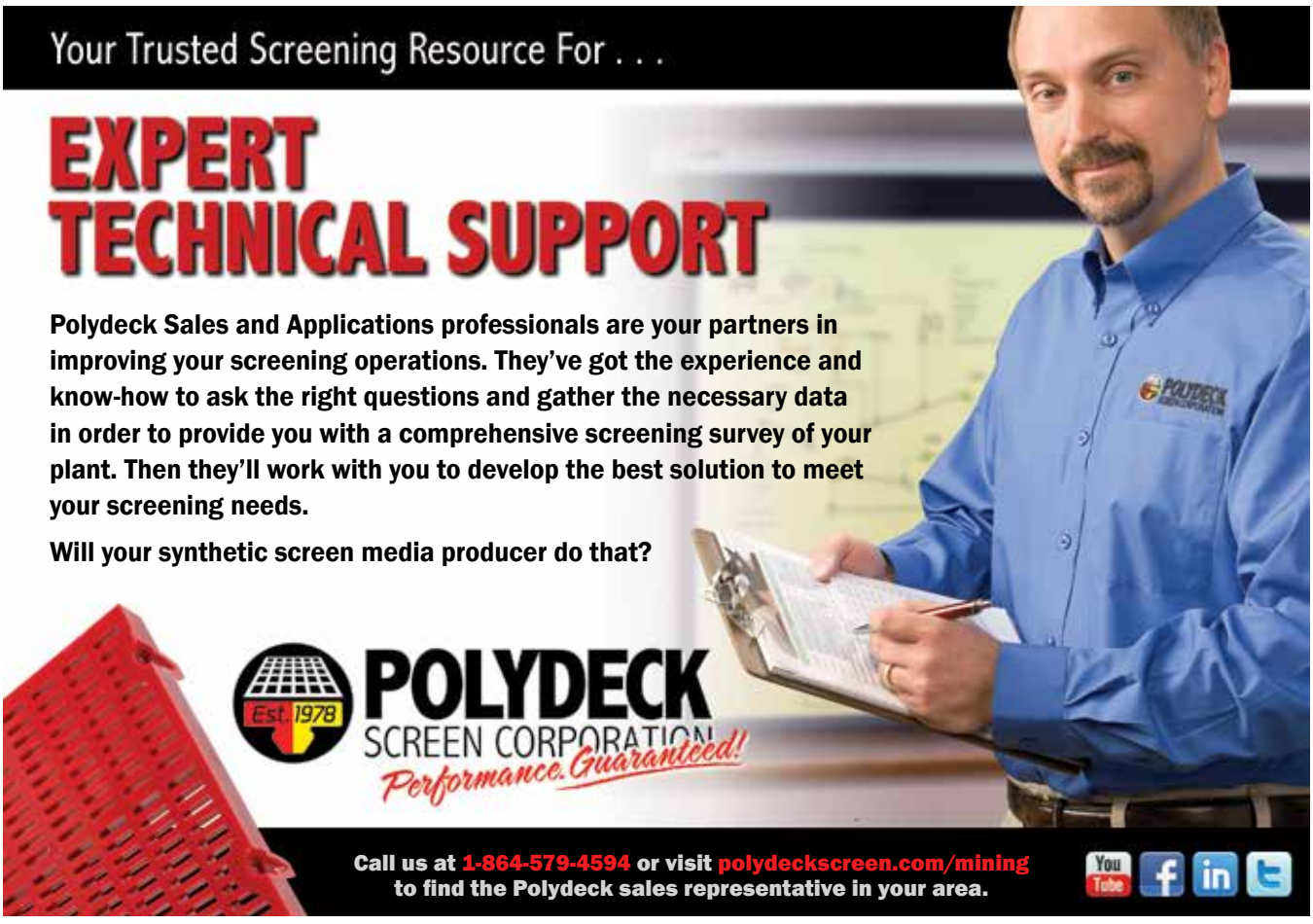
In Eq. (1), "rated capacity" should be understood as "nameplate capacity," i.e.: maximum capacity that a piece of equipment can achieve operating safely without exceeding its working parameters specified by its manufacturer.

Following all the above, one can see that operational effectiveness depends on several, often complex factors related or linked to autonomous machines themselves, maintenance support, the systems and infrastructure they work in, operational conditions and environment, work and asset management and others. Therefore, their impact on equipment or system productivity and their criticality may vary substantially from site to site. In the following sections, the avenues to improve operational effectiveness will be briefly presented and discussed.

Availability losses and means to reduce them

As mentioned before, availability depends on the combined aspects of reliability performance, maintenance performance and maintenance support performance (CAN/CSA, 1997). Obviously, in order to achieve high productivity, downtime should be kept as low as possible.

Reliability related issues. There are some strong reasons behind the claim that autonomous LHD equipment should be more reliable than man-operated machines. Sophisticated guidance and navigation systems greatly reduce possibilities of collisions with the drift walls, elements of mine



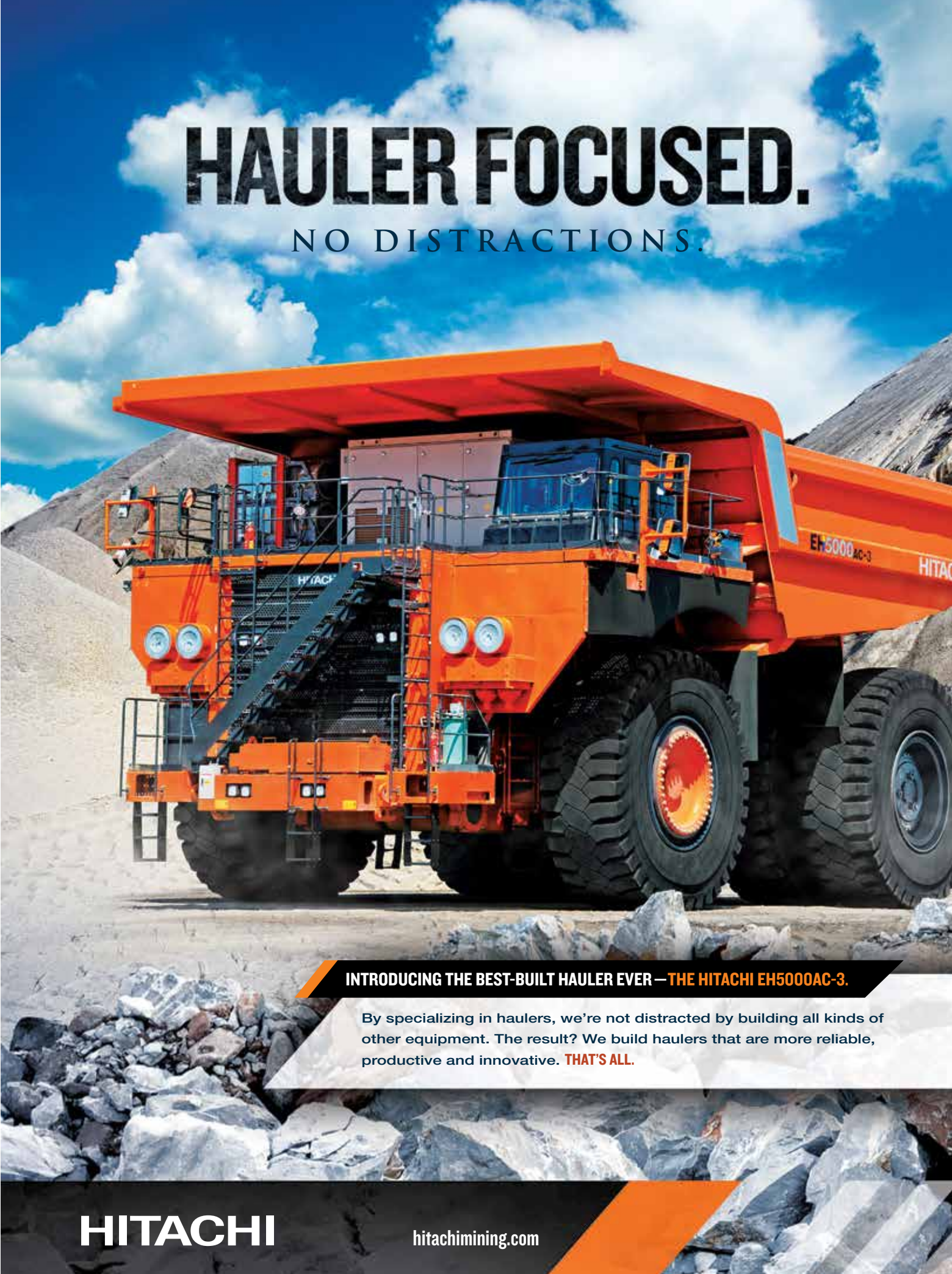

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Figure 3

Antenna in an underground mine.



infrastructure and with other machines. Modern autonomous equipment is also designed to learn the best practices and operate at the optimal working parameters, protecting the machines from abuse such as overloading, inappropriate gear shifting, tire slippage, etc. As operation is much smoother than in the case of man-operated equipment, life of components and consumables is longer.

Despite this, some argue that since automated equipment is more complex and sophisticated, there are more things to break. Reliability of autonomous loaders and trucks may be considered as a product of:

- Reliability of a "base machine" composed of the conventional subsystems (mechanical, electrical, hydraulics, etc.) identical to the man-operated machines.
- Reliability of the devices such as scanning lasers, cameras, computers, antennas, etc., found onboard autonomous equipment and absent on conventional machines.
- Reliability of offboard supporting infrastructure: hardware and software including video, voice and data communication systems, sensors, antennas, security gates, etc. (Fig. 3).

Therefore, in a harsh operating environment, they become more vulnerable and may fail in circumstances where ordinary machines would continue to operate. For example, dirty laser lenses impair the navigation system and may force the vehicle to shut down. In what concerns the supporting infrastructure, its malfunction may interrupt the working cycle of an individual machine or of the whole system. It may also be affected by other factors totally absent in conventional loading and haulage systems. In this context, as there are many sophisticated components (both on the machines and off board) critical with regard to safe and reliable operation, adequate schedules and scope of inspections and proactive maintenance programs should be carefully developed.

Working environment is also crucial. Well-designed, smooth and carefully maintained haul roads reduce vibrations and jolting and thus reduce risk of failures of fragile parts and components as well as tires. Attention should also be paid to careful loading of LHD buckets and truck boxes to avoid rock spillage that may cause damage to vehicles. Adequate rock support limits the risk of damage to the infrastructure and helps reduce risk of collision with fallen rocks or bulged walls.

Currently, it is difficult to compare reliability of autonomous and man-operated mine vehicles. To the best knowledge of the author, there have been only a few published studies focused on the actual level of reliability of autonomous loading and haulage equipment (Kumar and Vagenas, 1993; Hall et al., 1999, Gustafson et al., 2013a). The latter study is probably the only one done up until now focused on a comparison of reliability of manual and autonomous LHD. It was done on one manual and one semiautomatic LHDs, with the same age and specifications. The researchers have investigated and analyzed failure and repair data collected for during the period of three years and eight months. Contrary to some common beliefs and assumptions, no evidence that the LHD operated in an autonomous mode achieves higher reliability has been found. Actually, the number of failures of transmissions and engines was actually higher for the semiautomatic LHD. Manually operated machines had more chassis failures. This study, however was done only on two machines, so it is not necessarily 100 percent conclusive. Definitely more studies, particularly field ones, are necessary in order to fill this gap and get a better understanding of this issue.

Reducing downtime. Acting on reliability is extremely important, but, despite all efforts, in harsh mining environments, even the most technically advanced equipment will still fail. It should not be forgotten that downtime does not depend exclusively on the frequency of failures but, even more, on the time it takes to restore

a disabled machine to an up state. Downtime is composed of active maintenance time (corrective and proactive) and delays. In what concerns active maintenance time for autonomous loaders and trucks, it is difficult to compare it with man-operated machines. For the reasons mentioned previously, it is expected that autonomous vehicles should be more reliable. However, additional corrective and proactive maintenance actions must be performed on the devices exclusive for autonomous equipment. For example, in the Finsch Mine in South Africa, cleaning of scanning lasers and cameras must be done after each shift, despite particular attention paid to suppress the dust (Cook et al., 2008). In order to reduce downtime, these activities should be combined with other maintenance or service actions.

Unfortunately, downtime is not limited to active maintenance time. Although well-planned and prepared proactive maintenance action should not involve any delays, those inherent to corrective maintenance may have a substantial negative impact. Particularly, logistic delays, including travelling to unattended equipment or installation, pending arrival of spare parts, specialists, test equipment, information, etc., (CAN/CSA, 1997) may be critical. The first category seems to be a principal downtime contributor. Due to safety reasons, autonomous equipment operates in the zones normally closed for human workers. Every human intervention inside such zones requires shutting down all autonomous traffic and operation, with obvious negative consequences in terms of additional downtime or idle time. Such interventions may be unavoidable even in the case of some minor failures that cannot be corrected remotely, but in conventional systems, a machine operator himself would repair them in less time. Additionally, there is another potentially disturbing factor with future, fully autonomous mines in which less intense ventilation is intended to reduce operating cost. In such mines, breathable air may be lean in oxygen, and if the maintenance crew was to go underground, time needed to increase oxygen level to that safe for human workers could cause additional delays and, consequently, increase autonomous equipment downtime. In the opinion of this author, logistic delays may affect equipment's availability more significantly than in the case of the conventional equipment. Consequently, this factor should receive particular attention at the feasibility stage concerning implementation of autonomous equipment and systems. In order to reduce logistic and administrative delays the following means and/or steps are recommended:

- Coordinate major maintenance interventions inside the restricted zone with other mine activities that would bring autonomous operation to a halt anyway.
- Use all of the forced stoppages for minor maintenance actions inside the security zone.
- If a loader or truck fails and there is another one piece (or pieces) of autonomous equipment inside the restricted zone, if it is possible and justified, tow the failed unit out of the zone in order to restore automated traffic as soon as possible.
- Make extensive use of remote troubleshooting to reduce the time to diagnose the reasons of failure.
- Have an adequate support of the original equipment manufacturer to assist mine crews, if necessary.
- If possible, assure presence of well-trained maintenance personnel in the vicinity of the operation area to reduce travelling time.

In general, it may be assumed that maintainability of autonomous equipment should not be a major issue with regard to its productivity, except probably the maintenance of the supporting infrastructure. In the opinion of this author, it is rather maintenance support that may be far more critical.

Maximizing utilization

Ideally, in order to achieve maximum utilization, standby or idle time should be totally eliminated. In practice, however, there are several losses that reduce utilization rate. In the first place, some off-time losses may occur. They are due to statutory holidays and the work schedules other than a 24/7 schedule. This is usually a controllable factor and, in order to get the most of the autonomous equipment, scheduled working time should be maximized. Subsequently, there are some other scheduled time losses: operators' travel time, lunch breaks, shift changes, different kind of meetings, etc. Implementation of the autonomous equipment reduces idling significantly through placing operators on surface instead of underground, "hot seat" shift changes in a control room and better work management. Therefore, in a well-organized mine using autonomous equipment, these kinds of losses should be minimal and their negative impact almost unfelt.

Unfortunately, a fully operational and available autonomous machine may become idle due to the events related directly to the system

within which it works, such as:

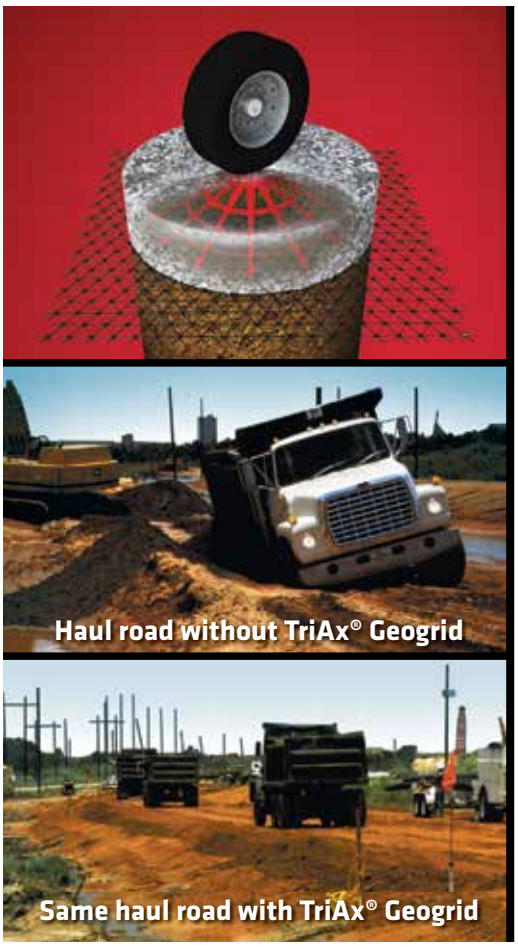
- Temporary unavailability of the remote operator attending another machine (if one operator controls more than one vehicle).
- Interference with man-operated equipment. In the Williams Mine in Ontario, Canada, the autonomous trucks share a certain zone with man-operated LHDs and trucks. Sporadically, they have to wait until the latter leaves the zone (Chadwick, 2008).
- Problems with the software running the system.
- Stoppages due to malfunction and subsequent maintenance actions on another autonomous vehicle or supporting infrastructure (antennas, sensors, security gates, etc.) and road maintenance.
- Shutdowns due to exceeding of limits of operational parameters such as speed or vehicle tilt.

The last category is the least critical, as in most cases the distant operator may take over the controls, remediate the problem, if necessary, and put the machine back to work in a short time.

In order to minimize these types of losses, it is highly desirable to avoid any interaction between autonomous and man-operated machines inside the protected security zone. If possible, this factor should be taken into consideration at an early planning stage, as it may have serious impacts on autonomous equipment achieved capacity. Careful planning and coordination of maintenance activities concerning loaders or trucks on one hand and those touching infrastructure, system software, roadways, etc., is one of the best means to reduce idle time.

Concerning external factors that may bring autonomous machines to a halt, the following may be mentioned:

- Problems at loading and dumping points (lack of muck or hangups in ore passes, oversize blocks at drawpoints and tipping points, etc.).
- Presence of obstacles (fallen rocks,



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hanging cables, displaced elements of mine infrastructure, etc.) or distortion of the drift profile (bulging of the floor bed, drift walls' convergence, etc.), recognized as abnormal by the machine's navigation system and leading to its stoppages.

- Entries of the authorized people not involved in autonomous equipment operation (geologists, surveyors, ground support crews, etc.).
- Stoppages caused by the breaches of the isolated zone (careless workers, alien objects, etc.).

In most of these cases, human intervention inside the security zone is required, so shutting down all autonomous traffic and operation is a must. These time losses are further aggravated by mandatory, time-consuming security procedures before restoring autonomous traffic. In the Williams Mine, it is estimated that between 30 and 60 minutes are necessary to return to the autonomous mode. In this respect, the coexistence between human workers and mobile equipment is far less problematic in conventional loading and haulage operations. As a result, potential gains in utilization of autonomous machines stemming from extended working time (less idle time), may be, in unfavorable conditions, offset by time losses that do not occur in the case of man-operated vehicles. In order to maximize utilization rate the following measures should be taken:

- If possible, design mine layout and plan loading and haulage operations in a way that does not involve interference between autonomous and man-operated equipment.
- Do not assign more than three machines to one remote operator, so that they can be adequately attended without too much idling losses.
- It is strongly recommended to plan carefully every intervention inside the security zone in order to avoid any incursion of a human worker that is not critical while the autonomous system operates safely and correctly. If the system is idle due to external reasons (like lack of muck or preparation for blasting), use this time to perform actions requiring human intervention inside the security zone.
- Train mine workers in order to reduce a number of unauthorized incursions into the isolated zone triggering alarms, followed by a shutdown of the traffic.

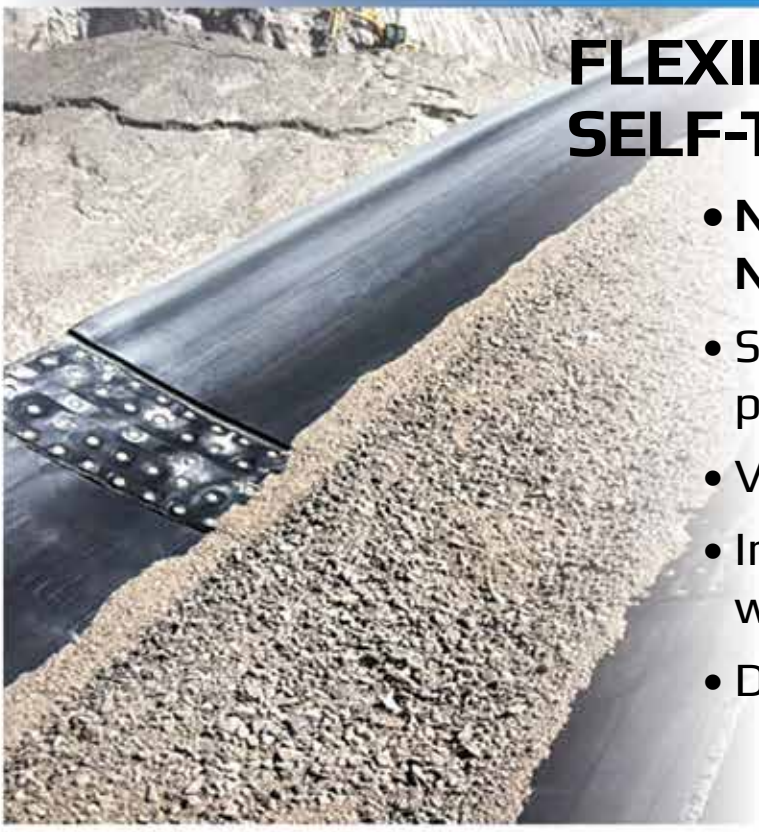
It is worth mentioning that autonomous equipment can operate in the situations where, for reasons of security, conventional machines could not. For example, in the Malmberget Mine in Sweden, the ability to tram regardless of shift patterns or blasting schedules has been estimated to increase daily production by between four and six hours (Caterpillar, 2008). In the Kemi Mine (Finland), following a roof collapse in a certain area of the mine, the autonomous Atlas Copco's ST-14 loader was put in operation in the area considered highly dangerous for manned machines (Moore, 2008; Gustafson, 2011). This way automation brings considerable gains in mine productivity.

Getting closer to rated capacity

Production efficiency of a loader or a truck depends on several factors. The most important ones include cycle time, payload and operator efficiency. Particularly, reducing cycle time is crucial. In this respect, autonomous machines seem to have a competitive edge on conventional man-operated machines. They learn to follow the optimal safe trajectory and maneuver with high precision at loading and dumping points. This eliminates almost totally time losses resulting from operator errors while positioning the machine. Optimal vehicle trajectory combined with the absence of human workers on their travel paths makes it possible to achieve higher tramming speeds. Autonomous machines also have another important advantage: cycle time is constant throughout the

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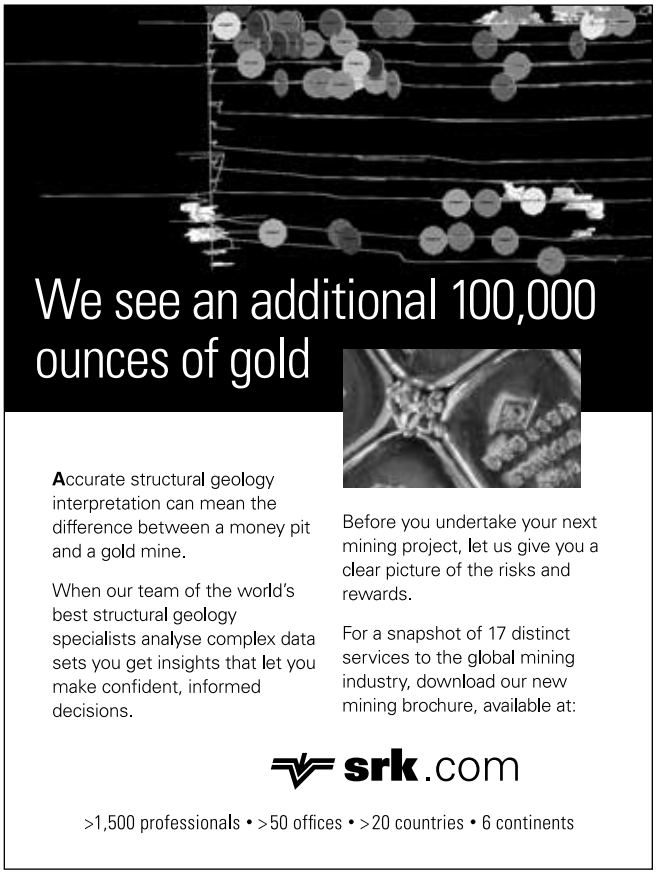
Figure 4

Sensors at a security gate help to keep operations efficient.



whole shift, whereas the operators seating in the cabins of conventional machines get tired with time and may tend to drive more slowly and maneuver less efficiently. There might be, however, a problem with the time to fill a bucket — the only operation executed remotely by an operator. Even though he receives video image and sound from the loading point, he is not physically on the machine, so, in some cases, the correct filling of the bucket remotely may be more problematic. Comparing production performance of two almost identical LHDs, one manual and one operated in an autonomous mode, Gustafson et al. (2013b) found that the latter produced less tonnes per engine hour due to longer bucket loading, which affects cycle time. Also, a natural tendency is to load it fully, but if the muck fragmentation is not optimal, some loose chunks may fall from the bucket during tramming. Spillage that follows may cause damage to the machines. So, for a given muck fragmentation, the operators should be able to find a balance between loading time and bucket fill factor. Adequate training of operators is definitely helpful to mitigate this problem. Nevertheless, as long as bucket filling is done by remote human operators, the effect of their fatigue and loss of concentration may still affect "quality" of this operation and thus actual production rate. As long as these operators remain indispensable, it will be hard to totally eliminate this problem.

In all, autonomous equipment seems to offer higher production efficiency than their conventional counterparts (Fig. 4). Again, to the best knowledge of this author practically no in-depth studies aimed to estimate the scale of improvement in this respect on the conditions of underground mines have been published.





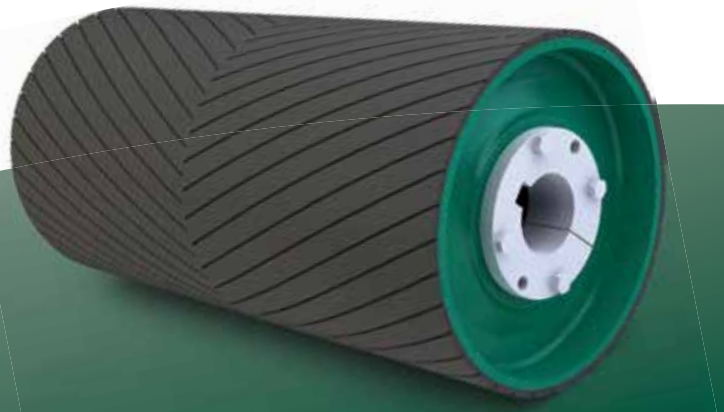
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Conclusions

In principle, atop of improved working conditions and safety, implementation of autonomous loading and haulage equipment is expected to bring the following benefits: increased fleet utilization, increased production, reduced maintenance costs, as well as optimized tramming speeds and smoother equipment operation. Increased fleet utilization ensures constant performance level enhancements and optimum use of the workforce. However, potential operation effectiveness gains stemming from the implementation of autonomous loading and haulage systems should not be taken for granted. Many issues must be resolved to maximize the benefits of automation. One such issue is to improve maintenance so that the vehicle can operate smoothly, with a minimum number of unplanned breakdowns. If automated vehicles unpredictably break down at any time and in any location, it is difficult to run an optimized automatic operation (Gustafson, 2011). As discussed above, there are many, sometimes complex, negative factors having a strong impact on operational effectiveness of autonomous loading and haulage equipment. It is obvious that the latter can reach the highest effectiveness in the mines designed and built with such systems in mind (Burger, 2006; Cook et al., 2008). More risk is involved in the mines built in a conventional way, whose layout, mining methods and work patterns may constrain capacity of autonomous systems. In this paper, some of the means and measures to maximize operational effectiveness have been discussed. Although some of them are not always applicable (particularly in older mines), applying them may help get the most from autonomous LHDs and trucks. Unfortunately, there have been almost no studies focused on operational effectiveness of such equipment and criticality of the factors that affect it adversely. More studies in this respect would definitely help get better understanding of their impact and criticality and suggest the most effective means and measures to mitigate their negative impact. Effective collaboration of technology providers, original equipment manufacturers and users is a key to get meaningful results. Unfortunately, due to confidentiality reasons, the access to valuable information and data is usually seriously restricted and many ideas how to improve operational effectiveness still await validation. ■

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Ontario investing in the Ring of Fire;

Province is moving forward with commitment of up to $1 billion

THE ONTARIO Ministry of Finance announced that the government is prepared to commit up to $1 billion to develop strategic, all-season industrial and community transportation infrastructure in the Ring of Fire mining district and is looking for a partner to help advance the development of the Ring of Fire in northern Ontario.

"Specifically, Ontario is calling on the federal government to equally match this funding to build the infrastructure required for this important project in the north that will create jobs and boost the northern economy," the Ministry of Finance said in a release.

The approach and priorities with respect to this investment will be established in partnership with First Nations, governments and industry partners through the development corporation.

Support for badly needed infrastructure could revive the fortunes of projects in the remote region, like Cliffs Natural Resources' Black Thor chromite project, and those of smaller companies like Noront Resources that are focused on the area, *Reuters* reported.

The 4,000-km^2 (1,500-sq mile) Ring of Fire is home to rich mineral deposits, and lawmakers say it could bring prosperity to northern Ontario much like the tar sands have to northern Alberta. But the swampy region lacks highways, rail lines or reliable power.

"We are committed to driving progress and investing in infrastructure development in northern Ontario's economy. We are looking to the federal government to match our commitment of $1 billion to unleash the Ring of Fire so that we can seize this tremendous economic opportunity of national importance," said Charles Sousa, Minister of Finance.

Cleveland-based Cliffs suspended most work on its $3.3 billion Black Thor in June, citing stalled talks with the province and other political and regulatory problems. It has struggled to win over aboriginal communities in the region.

The province is currently facilitating the creation of a development corporation to accelerate strategic infrastructure development in the region. The corporation will bring together key mining companies, First Nations, and the provincial and federal governments to develop, construct, finance, operate and maintain infrastructure supporting access to strategic resources in the Ring of Fire. ■

Newmont breaks off talks with Barrick;

Merger of gold mining giants could have saved $1 billion

TALKS OF A MERGER between the two largest gold mining companies in the world ended when Newmont Mining Corp. pulled out of the discussions with rival Barrick Gold Corp. on April 28.

The companies had several discussions about a merger that the two sides felt could save as much as $1 billion by taking advantage of an increased scale and reducing overlap primarily in Nevada, *The Wall Street Journal* reported on April 21. However, those talks stalled over a spin off of various assets.

Talks seemingly ended for good when Barrick announced Newmont's intentions to walk away.

"Although Barrick believes the interests of shareholders are best served through the completion of this business combination, Newmont's board has determined that the interests of Newmont's shareholders are best served by remaining independent," Toronto-based Barrick said in a statement.

Barrick was to offer Newmont shareholders a takeover premium of 13 percent, *Bloomberg* reported

The fallout from the breakup saw both sides pointing fingers.

In a letter to Barrick, Newmont Mining Corp. Chairman Vincent Calarco seemed to put the blame on Barrick. It said that, while the two companies "have been working hard" on merger discussions, "it has become evident to us over the past several weeks that the type of constructive, mutually respectful and partnership-oriented relationship necessary to realize the potential benefits of that combination does not yet exist."

Barrick said that after signing the term sheet, Newmont sought to back out of agreements to locate the merged company's head office in Toronto, define the assets to be included in a spinoff company, and to outline the roles of the chairman, chief executive officer and lead director.

Most of the efficiencies seen in a Barrick-Newmont deal would come from the combination of their operations in Nevada.

Most of the efficiencies seen in a Barrick-Newmont deal would come from the combination of their operations in Nevada, where they produce more than a third of their gold.

Newmont produced 55 t (1.77 million oz) of gold in Nevada last year, the company said in a Jan. 31 presentation, 35 percent of the total company gold output of 157.7 t (5.07 million oz). Barrick's Nevada production was about 86.8 t (2.79 million oz), based on company disclosures, 39 percent of last year's total.

Barrick and Newmont already are equal partners in the Kalgoorlie Mine in Australia and jointly own the Turquoise Ridge Mine in Nevada, with Barrick controlling 75 percent. ■

Mining at Mary River could begin in summer;

Baffinland announces final approval for iron mine

MINISTER OF Aboriginal Affairs and Northern Development Bernard Valcourt gave final approval for the Baffinland Iron Mines Corp.'s Mary River Mine on North Baffin Island.

The scaled-down version of the iron mine could begin its first phase of extracting ore this summer, Canada's *CBC News* reported.

The final approval followed recommendations from the Nunavut Impact Review Board (NIRB).

NIRB planned to hold a final workshop by conference call mid-May to prepare a project certificate, which would outline the terms and conditions, and the agencies responsible for them, that the mine will have to meet in order to keep operating.

Greg Missal, vice president of corporate affairs with Baffinland, said the company was pleased with the final terms and conditions imposed on the mine and will start mining iron ore at the site this summer or fall.

"It'll start to be trucked up to Milne Inlet and it'll be ready to be loaded onto ships during the open water season of 2015."

The dock that will carry that ore onto ships is now being designed and engineered.

Missal said that dock will determine the precise number of ships needed to move the ore.

Baffinland plans to ship 3.5-Mt/a (3.85 million stpy) of ore through Milne Inlet, using ships that carry between 70 kt and 90 kt (77,000 and 99,000 st). Baffinland expects to use about 55 ships during the open water season, in addition to ships carrying sealift supplies and fuel.

Missal said they plan to use dust suppression techniques to monitor and control dust from the road that will carry the ore to port.

The company will also consider providing compensation to hunters affected by changes to wildlife, in partnership with the Qikiqtani Inuit Association, which signed an Inuit Impact and Benefit Agreement with the company last fall.

The life of the mine is expected to be more than 20 years for the first deposit.

There are nine iron ore deposits overall. ■

Nautilus Minerals reaches agreement

with Papua New Guinea for offshore mining

NAUTILUS MINERALS, a Canadian mining firm, moved closer to beginning offshore mining production near Papua New Guinea (PNG) by finalizing an agreement allowing it to begin work on its Solwara-1 project, the *BBC* reported.

Nautilus Minerals plans to mine for copper, gold and other metals from a deposit 1,500 m (4,900 ft) below the sea.

Nautilus Minerals Inc. announced on May 9 that PNG's nominee for participation in the company's Solwara 1 project placed US$113 million into escrow, representing the balance of the funding for the state nominee's 15 percent share of the capital required to complete the development phase of the Solwara 1 project up to first production.

The company has been eyeing the seabed minerals off Papua New Guinea since the 1990s but has recently been locked in a lengthy dispute with the PNG government over the terms of the operation.

Under the agreement, PNG will take a 15-percent stake in the mine by contributing $120 million toward the costs of the operation.

Mike Johnston, chief executive of Nautilus Minerals, told *BBC News*: "It's taken a long time but everybody is very happy."

"There's always been a lot of support for this project and it's very appealing that it will generate a significant amount of revenue in a region that wouldn't ordinarily expect that to happen."

The mine will target an area of hydrothermal vents where superheated, highly acidic water emerges from the seabed, where it encounters far colder and more alkaline seawater, forcing it to deposit high concentrations of minerals.

The result is that the seabed is formed of ores that are far richer in gold and copper than ores found on land.

Johnston said that a temperature probe left in place for 18 months was found to have "high grade copper all over it."

A boom in offshore oil and gas operations in recent years has seen the development of a host of advanced deep sea technologies at a time when intense demand for valuable metals has pushed up global prices.

The mine, known as Solwara-1, will be excavated by a fleet of robotic machines steered from a ship at the surface.

The construction of the largest machine, a bulk cutter weighing 310 t (340 st), has just been completed by an underwater specialist manufacturer, Soil Machine Dynamics (SMD), based in Newcastle, U.K.

The agreement with PNG clears the way for Nautilus to order a specialist vessel to manage the operation. Mining could start within five years.

According to Nautilus, the mine will have a minimal environmental footprint, covering the equivalent of about 10 football fields and focusing on an area that is likely to be rapidly re-colonized by marine life.

"It's a resilient system and studies show that life will recover in 5-10 years," Johnston said. "An active venting site 1 km (0.6 miles) to the southeast has the same bugs and snails and the current will carry the bugs and snails to the mine site. We expect it to recover quite quickly."

But this will be the first attempt to extract ore from the ocean floor, so the operation — and the company's assurances about the impacts — will be watched closely.

So far, 19 licenses to search for seabed minerals have been awarded by the International Seabed Authority, the United Nations' body policing the industry.

The International Seabed Authority (ISA), which has welcomed the Nautilus Minerals agreement with Papua New Guinea, is currently drawing up guidelines for the environmental management of future seabed mining. ■

Joy Global to acquire Mining Technologies Int.

MINING EQUIPMENT maker Joy Global Inc. announced that it will acquire some of the assets of Mining Technologies International Inc. for $46.4 million, the *Journal Sentinel* reported.

Joy Global said it expects the acquisition to add to earnings in 2015.

Mining Technologies is a Canadian manufacturer of underground hard rock mining equipment. Joy Global said it will acquire "substantially all" of the assets associated with Mining Technologies' hard rock drilling, loaders, dump trucks, shaft sinking and raise bore product lines. Fiscal 2013 revenue for these product lines was about $90 million.

"This acquisition represents an exciting opportunity as we execute on our growth strategy to expand our underground mining product lines into the hard rock markets including nickel, potash, palladium, platinum, gold and copper," said Ted Doheny, Joy Global's president and chief executive officer.

Joy said in September it was laying off as many as 200 manufacturing plant workers in Milwaukee in response to a global slowdown in the mining industry that cut deeply into equipment sales. The company reported a 66-percent drop in quarterly earnings in early March, but said demand from miners for maintenance work was returning after more than a yearlong, industry wide struggle with a coal glut and weak prices. ■

Risk mitigation for openpit

mining in areas with old underground workings

by J. Duran

Mining at Newmont Mining's Phoenix's Mine is currently done by surface operation in the Fortitude and Bonanza pits at a combined rate of approximately 100 kt/d (110,000 stpd). A portion of the orebodies targeted by these pits was mined previously by underground mining methods, dating back to the mid-to late-1800s. Most of the underground workings (voids) are located in the west central area of the Bonanza pit.

The surface operation requires excavation through voids, and there is a risk of pit floor subsidence that has to be addressed. This article presents a review of the risk mitigation measures that were implemented to reduce risks to people and equipment working in the area.

Risk approach

The main approach is to produce mining plans that take into account the presence of voids and implement safety measures to keep adequate crown pillar dimensions in accordance to the rock mass quality and the void dimensions.

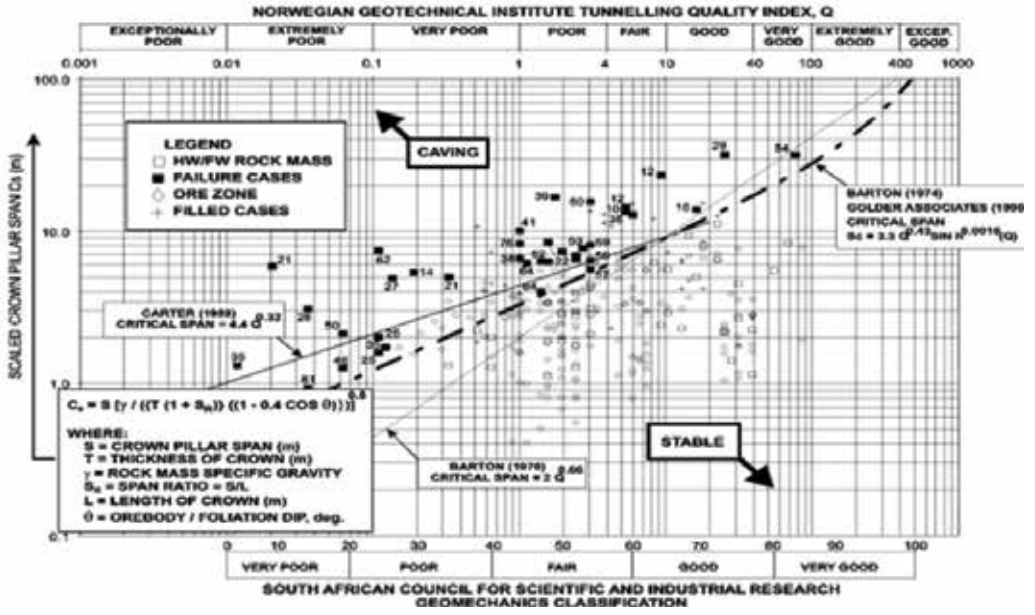
The main risks to this approach are the variability of the rock mass conditions and the accuracy of the void geometry and location.

Variability of rock mass conditions

The risk of the variability of the rock mass conditions is addressed by establishing a conservative design for the average anticipated rock quality. A safe crown pillar design is conducted using the empirical design approach proposed by Carter et al. (2008), which involves comparing the crown pillar thickness, span, and rock quality to documented case studies of stable and unstable pillars. A "scaled span (Cs)" is determined by scaling the actual span to account for the influence of various parameters (e.g., horizontal stress, rock quality, etc.). This methodology is a good starting point for determining conservative working crown pillar thicknesses for active mining, as the Carter empirical crown pillar design is intended for closure applications.

Figure 1

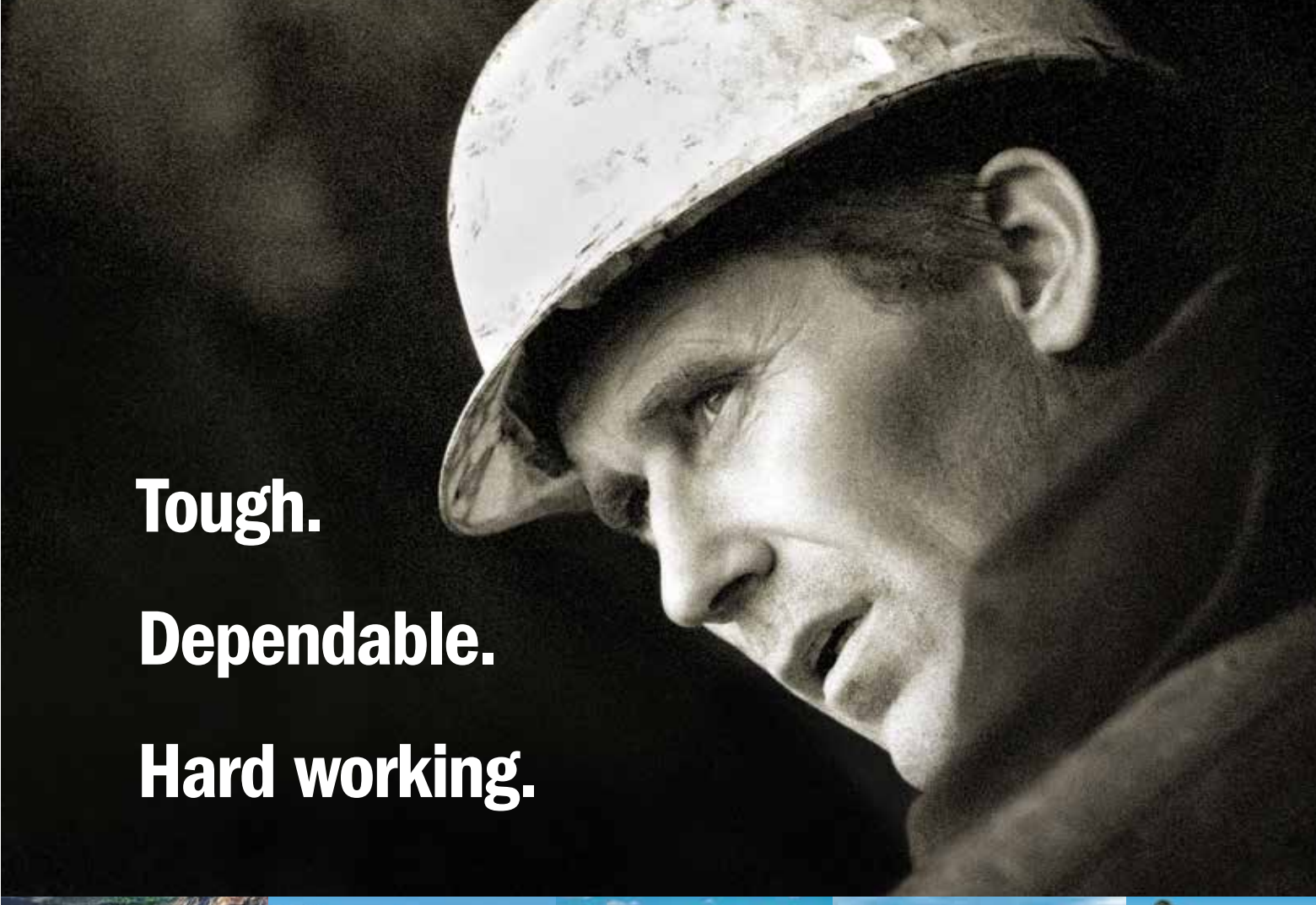
Scaled span concept chart (after Carter, 2000).



Accuracy of void geometry and location. The accuracy of the void geometry and location is fundamental to risk mitigation. The variability of the void location is mitigated by incrementally increasing their certainty according to the following approach:

1. Creation of a 3D model from historical documentation (survey data) using digitized old drawings that are scaled, rotated and moved to match current mine coordinates (Fig. 2).
2. Exploration drilling on a reduced pattern 15 m x 15 m (50 ft x 50 ft) within the potential void areas to rule out any big opening not

J. Duran, member SME, is geotechnical engineer consultant, Newmont Mining Corp., Battle Mountain, NV, email jofree.duran@newmont.com.







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Figure 2

Three dimensional model of the voids.

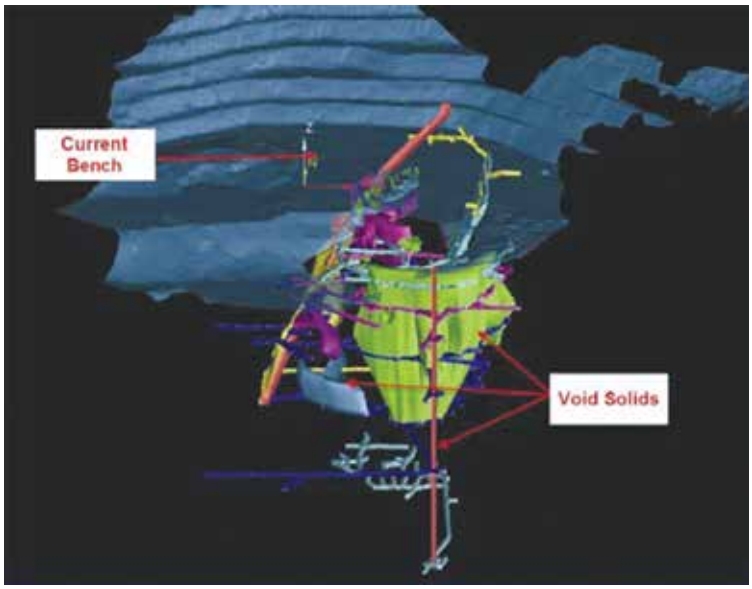
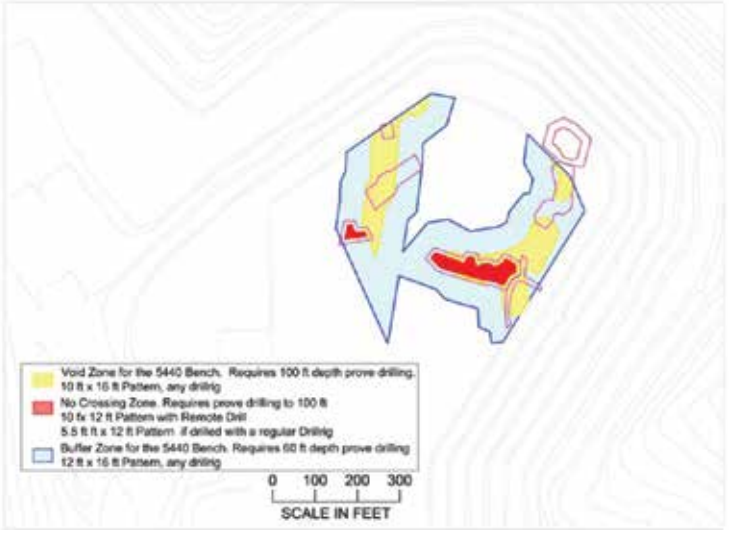


Figure 3

Buffer and void zones sample drawing.



captured in the historical documentation.

3. Creation of void and buffer zones to account for minor variations of the actual voids. These variations could be related to the accuracy of the historic information and the changes of the void geometry over time as a result of partial collapse (Fig. 3).
4. Drilling closely spaced patterns during production drilling to define areas of no voids and intersect existing voids.
5. Getting an actual 3D geometry and location of the intersected voids using a cavity autoscanning laser system (CALS) (Fig. 4).
6. Updating the 3D model with the latest information including probed areas with no voids and the actual 3D geometry and location of the voids.

Given this approach, the main risk is during the void/buffer probe drilling activities where the actual location and dimensions of the voids remains uncertain. This risk is mitigated by keeping a minimum probed thickness in accordance to the potential void dimensions.

A minimum crown pillar of 6 m (20 ft) is maintained for drift size voids (less than 3 m or 10 ft in span) and a minimum of 20 m (60 ft) is maintained to the voids of a greater span.

Additionally, the areas of higher risk are drilled using remote equipment (Fig. 5). Probe drilling plans are constantly updated with the most recent information.

Once probe drilling is finished, then the certainty of the location and geometry of the voids in increased greatly and mining work plans are generated that include:

- Reviewing plans and cross sections and other documentation showing the determined underground mine voids.
- Determining the status of mine voids, i.e. whether they are open, backfilled or partially collapsed, or water filled.
- Establishing a suite of operating procedures for mining near and through underground voids that match with production requirements, covering safe approach and access for personnel and equipment, blasting strategies, infill/backfill of voids, barricading procedures and general reporting procedures for all possible safety issues.
- Determining the likely stability of ground at the edges of underground voids and derive the positioning of safety barricades to minimize the risk to personnel or equipment working near mine voids — particularly near unfilled stopes.
- Determining of the safe thickness of "rib" pillars left between openpit walls and underground workings to ensure continued stability of the pit walls.
- Signoff procedures to ensure all aspects of void and safe access assessment have been followed and match well with existing data/assumptions.
- Establishing "no crossing zones" over the areas where there is a higher risk of pit floor subsidence. Mining of these areas is accomplished by far reaching with the shovel from outside of the perimeter of the designated no crossing zones.
- Backfilling the critical voids progressing from the outer edge into the center of the void gradually reducing the span of the void.

Critical activities include:

- Establishing safe working procedures and training.
- Reporting any intersected void in any area of the pit.
- Conservative approach burden to void height (6:1) for the first determination when a void is intersected. Work plans are created once the void is scanned and geometry of the actual void is known.
- Updating the void and buffer zones according to the latest information.
- Field demarcation of void and buffer zones to make the hazard visible.
- Keeping up to date the shapes on the display screen for the mining equipment.
- Quality control (design versus as built verification) of probe drilling in terms of probing holes location and depths.
- Verification of backfill quantities comparing the volume of the scanned voids and the quantity of placed backfill.
- Verification of backfill placement with camera inspection of backfilled holes from adjacent holes. ■

Figure 4

Sample of scanned void geometry.

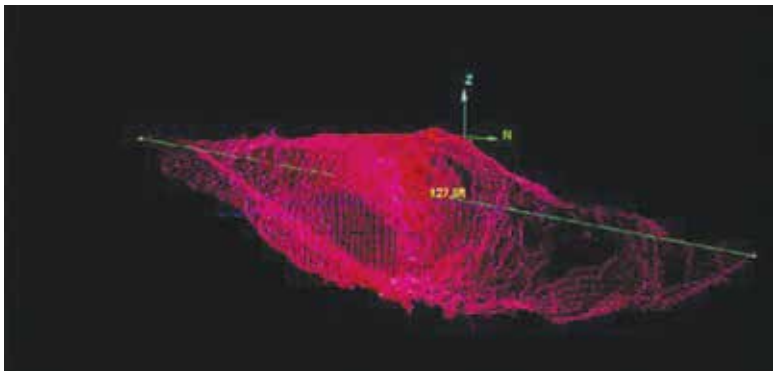


Figure 5

Remote control drilling of critical void areas.



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Excavators pass 100,000 hours at Yanacocha

Two Hitachi EX5500-5 front shovels achieved elite status October 2013 at the Yanacocha gold mine in Peru by surpassing 100,000 operating hours.

Both EX5500-5 machines – the predecessor to Hitachi's current EX5600-6 model – were delivered 14 years ago and have been working at numerous pits in the 251-km^2 (92-sq mile) openpit mine ever since. The first machine passed the 100,000-hour mark on Oct. 7, 2013, and the second only 22 days later on Oct. 29, 2013.

Yanacocha, which is owned by Newmont Mining Corp., is one of the largest gold mines in the world. It is situated roughly 30 km (18 miles) north of Cajamarca, high in the Andes Mountains, where extreme conditions exist. The material at the mine is abrasive. Weather can be a challenge and, at an altitude of 3,500 to 4,000 m (11,400 to 13,000 ft) above sea level, close attention needs to be paid to the engines.

"The longevity of these machines, particularly in the aggressive conditions that exist in Yanacocha, is a testament to the reliability, durability and efficiency of Hitachi excavators," said Craig Lamarque, division manager, Hitachi. "When Hitachi builds something, they build it right. That's why you can rely on our focused line of excavators and haulers."

Both machines were serviced at the mine in Yanacocha. In addition to normal maintenance, such as daily inspections, filter and oil changes, and hose inspections, the Yanacocha team changed components by condition or by hours. In addition, the swing bearings were changed every 20,000 to 40,000 hours and major structural components, such as the boom, arm, side frames and main frame, were changed or repaired upon inspection. ■

Global views of mining
from the "world's mining capital"

by William Gleason, Senior Editor



Sen. Joe Manchin (D-WV) delivers the keynote address at the 116th National Western Mining Conference and Exhibition in Denver, CO.

During the 116th National Western Mining Conference and Exhibition in Denver, CO, the host city was often referred to as world's mining capital, so it was fitting that the conference looked at the mining industry through a global lens.

In the current world economy, the mining industry must keep a sharp focus on such things as commodity prices and global supply and demand as well as local issues that can have a dramatic impact on a mine's social license to operate. In short, companies should mine locally but think globally.

During the three-day conference at the Colorado Convention Center, a range of global and local issues that effect the industry were discussed. A record 1,144 people attended the conference.

Sen. Manchin delivers opening keynote

From his days as Governor of West Virginia to his current role as a U.S. senator, Joe Manchin's political career is one that has been tied to the mining industry, publicly and personally, particularly coal mining.

On April 15, Manchin was the keynote speaker at the National Western Mining Conference.

Manchin, a Democrat, has adopted an all-of-the-above energy approach, has opposed the Obama administration, the U.S. Environmental Protection Agency (EPA) and, oftentimes, his own party on the issues of coal mining and global warming.

He was appointed to replace Sen. Robert Byrd, who died in 2010. Manchin serves as the chairman of the Senate Subcommittee on Public Lands, Forests and Mining. He is also a member of the Senate Armed Services; Banking, Housing and Urban Affairs; and the Energy and Natural Resources committees. And he is one of the few unapologetic supporters of mining in Congress.

In a sweeping speech, Machin said it was imperative that the mining industry work together to "rein in the EPA and stop demonizing the coal industry."

"There is a saying in politics that you'd better tell your story before someone else tells one against you, because it is better to be on offense than defense," Manchin said. "Right now we are playing defense."

Manchin has been on the front lines in the defense of coal's role in providing affordable and reliable energy, and he has opposed strict new emissions rules for coal-fired plants. "Coal is part of who we are, and we would not be the superpower that we are if it were not for the fuel and resources that we have right here in our own backyard," said Manchin, who turned to a chapter of American history to help make his point. "In 1943, Franklin Delano Roosevelt nationalized the coal mines, saying, 'A stopping of the coal supply, even for a short time, is a gamble with the lives of American soldiers and sailors and the security of our nation.' That is as true today as it was then, but we are not telling that story the way we should be."

If the United States was to take coal out of



A vibrant exhibit floor offered attendeess the opportunity to network during the 116th National Western Mining Conference and Exhibition in Denver, CO.

the energy mix, it would do little to cut global emissions, said Manchin. He said the United States consumes about 907 Mt/a (1 billion stpy), while the rest of the world consumes 6.3 Gt/a (7 billion stpy) of coal.

Along with U.S. Rep. Ed Whitfield (R-KY), Manchin is sponsoring a bill that would only allow the EPA to impose regulation standards that have been achieved for 12 straight months at six domestic power plants.

The bill has drawn the support of Democrats from energy-producing states including Sens. Heidi Heitkamp of North Dakota and Mary Landrieu of Louisiana. Manchin is still working to add cosponsors and hasn't yet asked for the support of Majority Leader Harry Reid.

Manchin is also deeply involved with mine safety and health.

As governor, he implemented and oversaw large-scale safety reforms to mining operations in West Virginia in response to the Sago Mine disaster in 2006. These changes served as the model for the first federal laws in 29 years to make improvements to mine safety. In 2010, he was again thrust into the national spotlight when the Upper Big Branch Mine explosion killed 29 miners in West Virginia.

He told the conference, "I would say to you the most important thing you can do is make sure everyone who works at your mine knows that the safety of each and every miner is number one and that they have the ability to stop that operation when there is something that jeopardizes their life or the life of another. When you have that attitude, I guarantee you will have better production and a better operation. I can tell you the price of the commodity and the equipment. I can't put a price on a life."

Workforce trends

In the grand scheme of things, mining, it would seem, plays a small role in the larger employment picture of the United States. After all, the industry directly employs about 340,000 people in the United States, which works out to be about one quarter of one percent of the entire workforce. However, this small group runs an industry that contributes about $16 trillion to the U.S. economy. The problem is this is a group that is projected to get much smaller in the coming years.

On April 16, SME Executive Director Dave Kanagy spoke about the impending workforce crisis at the Colorado Mining Association/ Mining and Metallurgical Society of America breakfast. SME recently released an update of its technical briefing paper, "Workforce Trends in the U.S. Mining Industry."

The study found that the population in the United States is expected to increase by more than 400 million by the year 2050, but the mining workforce is expected to decrease by 128,000 by 2019 and by 221,000 by 2029.

"The workforce shortage is the single greatest challenge that faces the mining industry today," said Kanagy. "By 2029, more than half the current workforce will be retired, and the number of qualified science and engineering professionals graduating from U.S. schools will not meet the capacity required to fill these vacancies."

Kanagy noted that the crisis is not dictated by the United States alone. Increasing populations around the world and the rapid growth of emerging nations is increasing demand for all commodities, and with that demand comes international competition for qualified people. He also noted that as the industry strives to replace retiring members of the workforce and works to meet demands, there are sure to be additional challenges, such as maintaining a safe work environment.



The Henderson Mine in Empire, CO was recognized for its safety record and environmental stewardship by the Colorado Mining Association.

Global influence on coal

Speaking of reducing carbon emissions, Deck Slone of Arch Coal said, "We cannot simply shrink our way to a low carbon future."

Slone told the audience that reducing emissions from coal-fired energy plants in the United States is only part of the solution because the rest of the world continues to turn to coal for energy needs, even as the United States is turning away.

Between 2002 and 2012, there was a 55-percent increase in coal consumption on a global level.

"We expect that growth to continue, and not just from China and India," Slone said.

New coal plants are being built in Africa, Europe, South America and Japan.

The demand from emerging markets has led U.S. coal producers to look toward the export market that, according to Slone, is showing excellent growth potential, with 41 export terminals being built on the West Coast and 86 on the East Coast of the United States.

Domestically, Slone said, the U.S. Energy Information Administration projects coal to supply less than 40 percent of the nation's energy needs by 2020, compared to 2008, when it supplied more than 50 percent.

Natural gas is partly to blame, as is a tough regulatory environment.

Stakeholder relations

Earning and maintaining a social license to operate has become one of the hot-button topics in the industry. Once considered a so-called "softer" issue, it is now among the most important issues any mining company must consider. The ability to communicate instantaneously has empowered a number of special interest groups that oppose mining on one level or another. And with a proper public relations campaign, these small, sometimes grassroots efforts, can blossom into something large enough to halt a multi-billion dollar project in its tracks: See the Pascua Lama project in Peru or the Pebble Project in Alaska.

Maureen Upton, principal, Resource Initiatives and chair of the conference, spoke about the need for mining companies to engage all stakeholders in an open and honest manner.

The conference also hosted a session on mining in Colorado – transition, transactions and mine development; mine safety and health; uranium mining and environmental challenges, including regulations and policy regarding climate change and the greater sage grouse on public lands.

Awards

During the conference, Colorado mining operations were recognized for excellence in environmental stewardship, reclamation and safety by the Colorado Mining Association.

The "Best of the Best" environmental stewardship for coal went to Mountain Coal Co. and its West Elk Mine in Somerset, CO, while the "Best of the Best" hardrock award went to Climax Molybdenum Co.'s Henderson Mine and Mill in Empire, CO.

Western Fuels Colorado and Mountain Coal Co. received top honors for "Outstanding Reclamation" from CMA. Mountain Coal's West Elk Mine, Honeywood Coal Company's Hamilton Mine, Chevron Mining's Edna Mine and Kerr Coal Co.'s Marr Mine were also recognized for their reclamation efforts in 2013.

The top safety awards went to West Elk, New Horizon, Henderson and American Gypsum mines.

The West Elk Mine won for safest underground coal; the Henderson Mine posted the best safety record among large metal mines; the New Horizon Mine in Montrose County was honored in the small surface coal mine category and American Gypsum's Eagle Gypsum Mine was recognized in the top nonmetal mine category.

Complete lists of award winners and descriptions of the awards and the winning operations can be found at CMA's website www.coloradomining.org.

The 117th National Western Mining Conference and Exhibition will take place Feb. 15-18 in conjunction with the 2015 SME Annual Conference & Expo in Denver, CO. ■



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Using node analysis
modeling techniques to predict cab filtration system performance

by J.A. Organiscak, A.B. Cecala and J.D. Noll

Abstract ■ Enclosed cab filtration systems are typically used on mobile mining equipment to reduce miners' exposure to airborne dusts and diesel particulates generated during mining operations. Various filter configurations can be used within the heating, ventilation and air conditioning (HVAC) systems of cabs to remove the airborne contaminants. The air cleaning performance of cab filtration systems is highly dependent on the efficiency of the air filters, the number of filters used and their placement within the HVAC system. This paper shows how to mathematically model cab filtration systems and illustrates a methodology for developing other cab filtration system design models. Node diagrams of several filtration system circuits are illustrated with their mathematical models at steady state airflow and concentration conditions. Laboratory and field data are presented to demonstrate the validity and utility of modeling enclosed cab air cleaning performance. The paper concludes that incorporating multiple filters throughout the HVAC system improves the air cleaning performance and robustness of the cab filtration system design.

Mining Engineering, 2014, Vol. 66, No. 6, pp. 52-59.
Official publication of the Society for Mining, Metallurgy & Exploration Inc.

Introduction

Enclosed cabs are an engineering control that can provide a safe, comfortable and healthy worker environment for equipment operators. Most modern enclosed cabs have heating, ventilation and air conditioning (HVAC) systems for maintaining a comfortable temperature and a breathable quantity of air for their occupants. Various levels of filtration can be incorporated into the HVAC system to improve the ventilation quality of the air inside the cab by removing airborne pollutants such as dusts and diesel particulates. Previous enclosed cab dust filtration system field studies were conducted by the National Institute for Occupational Safety and Health (NIOSH) at mining operations, and these studies showed that the respirable dust reduction or protection factors (outside/inside concentrations) ranged from 3 to 89 (Organiscak et al., 2004; Chekan and Colinet, 2003; Cecala et al., 2004; Cecala et al., 2005; Cecala et al., 2012a). The two key components attributed to the more effective cab dust control results were an efficient filtration system and an effectively sealed cab (good cab integrity) for achieving positive interior pressurization (Cecala et al., 2013).

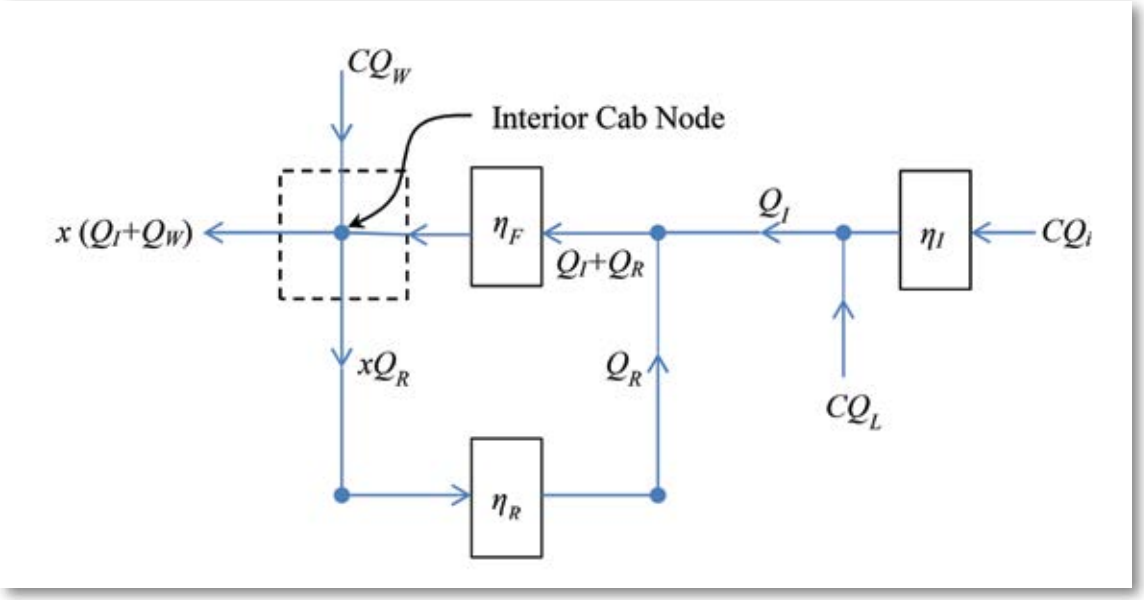
Previous laboratory experiments were conducted to methodically study the key design factors of effective cab filtration systems. These laboratory experiments examined the effects of intake filter efficiency, intake filter loading, intake air leakage around the filter, recirculation filter use and wind on cab filtration system performance (Organiscak and Cecala, 2008a; Organiscak and Cecala, 2008b). The experimental cab test results showed that intake filter efficiency and recirculation filter use were the two most important influential factors on cab filtration system penetration performance. The addition of a recirculation filter to the cab's filtration system significantly reduced its particulate penetration by an order of magnitude and reduced the time to reach its lowest stable concentration after the entrance door was closed by approximately 60%. Finally, a mathematical model was developed that describes cab particulate penetration in terms of intake filter efficiency, intake air quantity, intake air leakage, recirculation filter efficiency, recirculation filter quantity and wind penetration (Organiscak and Cecala, 2008b).

The enclosed cab filtration systems previously studied by NIOSH on mine

J.A. Organiscak, A.B. Cecala, members SME, and J.D. Noll are mining engineers and research chemist, respectively, at the National Institute for Occupational Safety and Health, Pittsburgh, PA. **Paper number TP-13-049. Original manuscript submitted October 2013. Revised manuscript accepted for publication January 2014. Discussion of this peer-reviewed and approved paper is invited and must be submitted to SME Publications by Sept. 30, 2014.**

Figure 1

Three-filter cab system with final filter downstream of intake and recirculation filters (*Q*'s denote air quantities, *x*'s and *C*'s denote contaminant concentrations and *η*'s denote filter efficiencies).



vehicles during field evaluations filtered the HVAC intake and recirculation airflows. Several of these cab filtration system systems also incorporated a third final filter downstream of the intake and recirculation filters (Chekan and Colinet, 2003; Cecala et al., 2004; Cecala et al., 2012a). The most recent field study of two underground limestone mine vehicle cabs (face drill and roof bolter) that used a three-filter HVAC system design (intake, recirculation and final filters) provided protection factors greater than 1,000 on submicron particles (0.3 to 1.0 µm), measured with particle counters after steady state interior cab concentration was reached (Cecala et al., 2012a). These high cab protection factors were regularly attained over an extensive range of intake and recirculation airflows measured during a seven-month field study. Since the mathematical model previously formulated from the laboratory study for a two-filter system (intake and recirculation filter) cannot be applied in its current form to examine the performance range of this three-filter system design (intake, recirculation and final filter), a new, three-filter cab filtration model was devised. The objective of this paper is to illustrate a methodology to formulate cab filtration system models and verify their utility in designing and predicting cab performance from field and laboratory data.

Modeling methodology

The two-filter cab filtration model previously developed was a time-related mass balance (differential equation) inside a control volume (cab) that was converged to a steady state solution as time approached infinity (Organiscak and Cecala, 2008b). The methodology that was used and illustrated in formulating a three-filter model is a mass balance of contaminants in a cab filtration circuit at steady state conditions. Steady state conditions are the lowest contaminant concentrations achievable inside the cab at constant outside contaminant concentrations and filtration system airflow quantities. This simplifies the model development to drawing out a node diagram of airflow circuit for the filtration system, devising the mass flow equation into and out of the node inside the cab, and algebraically solving the mass flow equation for the ratio of the outside concentration entering and leaving the cab filtration system.

Mathematical formulation of cab filtration systems. Figure 1 illustrates the node diagram of the three-filter system used and studied on vehicle cabs in an underground limestone mine (Cecala et al., 2012a). As shown in this particular filtration system, the final filter is downstream of the intake and recirculation filters. Outside contaminants enter into the filtration system circuit through the intake filter, leakage around the intake filter and direct penetration into the cab enclosure openings when wind velocity pressure exceeds cab pressure. Some of the filtered interior cab air is pushed outside by the intake airflow and any outside wind penetration, while the remaining portion of the cabin air is recirculated through the recirculation and final filters. The filtration system model is formulated as an equality of the incoming contamination mass to the exiting contamination mass at the interior cab node as defined in Eq. (1):

$$\text{Mass}_{\text{in}} = \text{Mass}_{\text{out}} \tag{1}$$

Additional contaminants can be brought into the cab enclosure on worker clothing and boots and later generated inside the cab interior through worker activities; however, development of this model primarily focuses on outside airborne contaminants that penetrate the cab filtration system, excluding worker-generated sources.

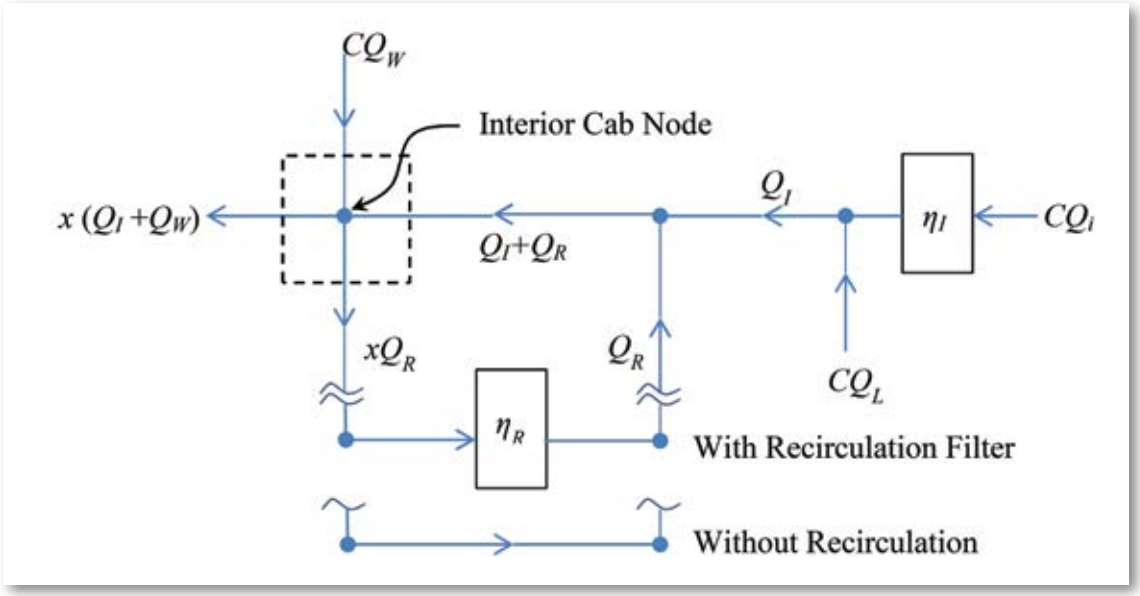
The incoming mass is what penetrates the cab filtration system and the outgoing mass is what leaves the cab interior and is recirculated through the filtration system, as shown in Eq. (2):

$$\left[CQ_i(1-\eta_I)+CQ_L+xQ_R(1-\eta_R)\right](1-\eta_F)+CQ_W = x(Q_I+Q_W)+xQ_R \tag{2}$$

where: C = outside contaminant concentration penetrating the filtration system
x = inside cab contaminant concentration (interior cab node)

Figure 2

Two- and single-filter cab systems with and without a recirculation filter, respectively (*Q*'s denote air quantities, *x*'s and *C*'s denote contaminant concentrations and *η*'s denote filter efficiencies).



η = filter reduction efficiency, fractional
1 - η = filter penetration, fractional
Q = airflow quantity
l = intake air leakage, fractional

With filter efficiency and air quantity subscripts:

i = filtered intake air
F = final
I = intake
L = leakage
R = recirculation
W = wind

Since $Q_I = Q_L + Q_i$ and $Q_L = Q_I l$, the substitutions of $Q_i = Q_I(1 - l)$ and $Q_L = Q_I l$ are made into Eq. (2):

$$\left[CQ_I(1-l)(1-\eta_I) + CQ_I l + xQ_R(1-\eta_R)\right]\times (1-\eta_F) + CQ_W = x(Q_I + Q_W) + xQ_R \quad (3)$$

The terms within the brackets are multiplied and simplified:

$$\left[CQ_I(1-\eta_I + l\eta_I) + xQ_R - xQ_R\eta_R\right](1-\eta_F) + CQ_W = x(Q_I + Q_W) + xQ_R \quad (4)$$

The bracketed intake and recirculation terms are multiplied by the final filter penetration term:

$$\left[CQ_I(1-\eta_I + l\eta_I)(1-\eta_F)\right] + xQ_R - xQ_R\eta_F - xQ_R\eta_R + xQ_R\eta_R\eta_F + CQ_W = x(Q_I + Q_W) + xQ_R \quad (5)$$

The outside and inside concentration terms are rearranged to opposing sides of the equation:

$$CQ_I(1-\eta_I + l\eta_I)(1-\eta_F) + CQ_W = x(Q_1 + Q_W) + xQ_R\eta_F + xQ_R\eta_R - xQ_R\eta_R\eta_F \quad (6)$$

which, simplified and rearranged, results in:

$$C\left[Q_I(1-\eta_I + l\eta_I)(1-\eta_F) + Q_W\right] = x\left[Q_I + Q_R(\eta_R + \eta_F - \eta_R\eta_F) + Q_W\right] \quad (7)$$

Next, we solve for protection factor (*PF*) ratio or penetration (*Pen* = 1/*PF*). The equation below was solved for protection factor and can easily be inverted to determine penetration:

$$PF = \frac{C}{x} = \frac{Q_I + Q_R(\eta_R + \eta_F - \eta_R\eta_F) + Q_W}{Q_I(1-\eta_I + l\eta_I)(1-\eta_F) + Q_W} = \frac{1}{Pen} \quad (8)$$

(for the three-filter model.)

This equation can be reduced to a two-filter model (intake and recirculation filter only) as shown in Fig. 2 by substituting a zero for the final filter efficiency. The equation can also be reduced to a single-intake filter model as shown in Fig. 2 by additionally substituting a zero for the recirculation filter. These reduced models are shown below. The wind penetration quantity into the cab is zero ($Q_W = 0$) for all models when the interior cab pressure is greater than the exterior wind velocity pressure.

$$PF = \frac{C}{x} = \frac{Q_I + Q_R\eta_R + Q_W}{Q_I(1-\eta_I + l\eta_I) + Q_W} = \frac{1}{Pen} \quad (9)$$

(for the two-filter model without final filter.)

$$PF = \frac{C}{x} = \frac{Q_I + Q_W}{Q_I(1-\eta_I + l\eta_I) + Q_W} = \frac{1}{Pen} \quad (10)$$

(for the single-intake filter model.)

Note: In the previously formulated two-filter model (in-

take and recirculation filter), the wind penetration airflow (Q_W) was only accounted for as incoming mass concentration (C) into the cab (Organiscak and Cecala, 2008b). As an oversight in its development, the outgoing mass concentration (x) from wind penetration (Q_W) was not included in that model and does not appear in both the numerator and denominator of that model. However, when the cab enclosure is adequately pressurized at or greater than the exterior wind velocity pressure, the wind penetration airflow (Q_W) can be considered to be negligible or zero and the models agree. For particular situations like an open door, open window or poorly sealed cab with no cab pressure, notable quantities of air can penetrate the cab enclosure from the outside and Eqs. (8), (9) and (10) would more accurately represent these types of conditions.

Cab performance measurements

In order to authenticate the cab filtration system models, airflow quantities, filter efficiencies and cab airborne particulate reductions must be measured at or near steady state conditions in an unoccupied cab. These types of cab measurements were initially conducted in the laboratory on NIOSH's experimental cab test apparatus for single- and two-filter systems (Organiscak and Cecala, 2008a; Organiscak and Cecala, 2008b). A three-filter cab system design was more recently studied on an underground limestone face drill and roof bolter cabs over a seven-month period. Airflow and particle counting measurements were completed between production shifts on the surface (Cecala et al., 2012a). Since filter efficiencies cannot easily be measured in the field, the known or specified filter efficiencies were used for the mathematical modeling, while the unspecified filters were tested in the lab on NIOSH's experimental cab test apparatus to determine their filter efficiencies.

Particle counting measurements. The cabs' protection factors were measured by using two model ARTI/Met One HHPC-6 particle counters (Hach Ultra Analytics, Grants Pass, OR) to simultaneously sample and record the inside and outside cab particle size concentrations for one-minute periods over a 30-minute test (with a recirculation filter) or a 45-minute test (without a recirculation filter), as previously discussed for NIOSH's laboratory cab experiments (Organiscak and Cecala, 2008a; Organiscak and Cecala, 2008b). These instruments count airborne particles within the six-channel size ranges of 0.3-0.5 µm, 0.5-0.7 µm, 0.7-1.0 µm, 1.0-3.0 µm, 3.0-5.0 µm and > 5.0 µm. The test medium was airborne particles present in the ambient air surrounding the unoccupied stationary cab enclosure with the filtration system operating. The inside and outside cab instruments were alternated for an even number of test replicates and were expected to average out any instrument sampling biases between the tests. At least four test replicates were conducted during each of the laboratory test conditions but only two test replicates were conducted during the field studies given the time constraints at the mine site. The last 15 minutes of data from each test replicate were used to calculate the average outside and inside cab concentrations during the lowest steady state particle count conditions inside the cab. The protection factors were determined from the cumulative submicron (0.3-1.0 µm) particle concentrations because most of the ambient air particles resided in this size range. A protection factor for each test replicate was determined by dividing the average outside particle concentration by the average inside particle concentration with the replicates averaged for the cab protection factor at the operating test condition. The protection factor represents a reduction ratio of all the exterior and interior particles removed by the cab filtration system.

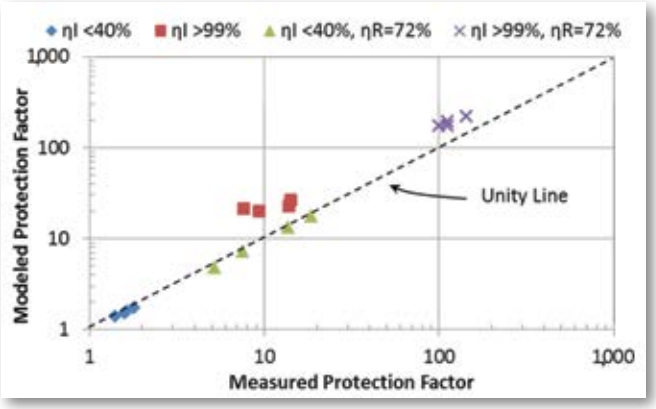
The submicron particle (0.3-1.0 µm) collection efficiencies of the filters used in the laboratory experiments were also measured with MetOne HHPC-6 particle counters immediately upstream and downstream of the filter on NIOSH's experimental cab test apparatus. Intake filter efficiencies were concurrently measured during each cab test by sampling downstream of the filter with a third MetOne particle counter (Organiscak and Cecala, 2008b). The recirculation filter efficiency was measured separately from the laboratory cab tests by sampling immediately upstream of the filter with an open cab door and isokinetically sampling immediately downstream of the filter in the recirculation ductwork with the intake air ducts closed (Organiscak and Cecala, 2008b). The recirculation filter tests were conducted at a comparable airflow quantity to the experimental laboratory tests that were used to quantify cab protection factors. Eight 15-minute test replicates were conducted with two particle counters, rotated between the upstream and downstream sampling locations during each test.

Independent filter tests were also conducted on NIOSH's experimental cab test apparatus with the unrated intake and recirculation filters (prefilters) used in the field study for the three-filter system. The final filter and one of the intake filters used during the field studies had an American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) minimum efficiency reporting value of 16 (MERV 16, efficiency ≥ 95% down to 0.3 µm particle sizes) (ASHRAE, 1999). The MERV 16 final filters and unrated recirculation filters were used in the two cab filtration systems field tested, with one of the cabs using an unrated intake filter and the other cab using a MERV 16 intake filter. A more detailed description of the filters used in the field study can be found in Cecala et al., 2012a. The unrated recirculation and intake filters (no ASHRAE MERV rating) used upstream of the MERV 16 final filter during the field study were tested in the laboratory for their submicron collection efficiency. Each of these filters was separately tested in a new and used (dust-loaded) condition with MetOne HHPC-6 particle counters on NIOSH's experimental cab test apparatus. Eight 15-minute test replicates were conducted with two particle counters, rotated between the upstream and downstream sampling locations during each test condition at comparable airflows observed in the field. Filter efficiencies were determined for each test condition and averaged for the eight test replicates to estimate the low and high range of filter efficiencies during the long-term field study.

Airflow and cab pressure measurements. Airflow readings were measured for the intake and recirculation circuits of the cab enclosures' filtration system to examine the cab operating effects of different filter combinations. For NIOSH's experimental cab test apparatus, the intake airflow velocity was centerline measured inside the 7.6-cm- (3-in.-) diameter PVC intake pipe with a TSI Model 8346 Veloci-

Figure 3

Comparison of laboratory-measured cab protection factors to the modeled protection factors.



CALC Hot Wire Anemometer (TSI Inc., Shoreview, MN). The recirculation airflow was measured with an ALNOR standard balometer capture hood (TSI Inc., Alnor Products, Shoreview, MN) placed over the inlet side of the recirculation filter. The experimentally controlled air leakage path bypassing the intake filter was measured with a TSI Model 4040 thermal mass flowmeter (TSI Inc., Shoreview, MN). During the field study, VELOCICALC hotwire anemometer models 8346 or 9555 (TSI Inc., Shoreview, MN) were used to measure the centerline air velocity inside the middle of a 122-cm-long (4-ft-long) section of smooth 10.2-cm-diameter (4-in.-diameter) PVC pipe that was added to the inlet of the intake filtering unit. For the recirculation component, 1-min moving traverse velocity measurements were made with a vane anemometer (Davis Instruments, Vernon Hills, IL) over the recirculation filter inlet area. A more detailed description of these measurements can be found in Organiscak and Cecala, 2008b and Cecala et al., 2012a.

The cab's inside-to-outside differential static pressure was also measured in the laboratory and field to ensure that cab pressurization was achieved. Cab pressure measurements were taken with either a 0.0-125 Pa (0.0-0.5 in. water gauge) magnehelic differential pressure instrument (Dwyer Instruments Inc., Michigan City, IN) or a DP-CALC Model 5825 micromanometer (TSI Inc., Shoreview, MN).

Cab filtration system performance results

The laboratory and field cab filtration system protection factor measurements were compared to those modeled from filter efficiencies, airflow quantities and fractional air leakages measured at various test conditions. During the laboratory experiments, almost all of the model variables were directly measured during the test conditions with the exception of the recirculation filter efficiency, which was measured separately from the cab testing. Therefore, the laboratory filtration system protection factor measurements can be directly plotted against the modeled results. During field testing, the three-filter efficiencies changed with filter dust loading as indicated by the reduction in intake and recirculation airflow quantities and the increase in protection factors measured during the study (Cecala et al., 2012a). Given filter efficiency changes with dust loading, the three-filter cab filtration system was modeled for a lower and upper limit curve at the various recirculation-to-intake airflow ratios measured in the field with new and used (loaded) filters. The two cabs' protection factor measurements were plotted at the various recirculation to intake airflow ratios to verify if the field results were within the models' predicted lower and upper operating ranges.

Laboratory results. Figure 3 shows an *x*-*y* plot of the measured and modeled protection factors for a single-intake filter system (Eq. (10)) and a two-filter system (Eq. (9)), with an intake and recirculation filter. This figure plots the average measured cab protection factors (*x*-axis) versus the modeled protection factors (*y*-axis), using the average cab operating variables measured at the different intake and recirculation filter conditions reported from the laboratory experiments (Organiscak and Cecala, 2008a; Organiscak and Cecala, 2008b). As illustrated in this graph, there is good positive correlation (correlation coefficient, $r = 0.995$, at significance level $p < 0.02$) between the measured and modeled cab protection factors. A notable difference in protection factors was also observed between the two intake filters tested (filter efficiencies, $\eta_I < 40\%$ and $\eta_I > 99\%$) and when the recirculation filter ($\eta_R = 72\%$ efficiency) was added to the filtration system. Therefore, filter efficiency and the number of filters used in the filtration system had a significant effect on cab protection factor performance and can be reasonably modeled at steady state operating conditions, knowing the filter efficiencies, system airflow quantities and air leakage bypassing the intake filter.

Field results. Cab protection factor modeling was conducted using new and used filter efficiencies over the range of recirculation-to-intake airflow ratios measured during the field studies (Cecala et al., 2012a). Table 1 shows the laboratory testing conditions for the unrated intake and recircu-

Table 1

Intake and recirculation filter test conditions and collection efficiency results, average [range].

Unrated filters tested	Filter condition (new/used)	Filter airflow (m^3/hr)	Differential pressure (Pascals)	Filter efficiency for 0.3–1.0 μm particles (fractional)
Intake filter	New	120 [119–121]	62.3	0.228 [0.188–0.262]
Intake filter	Used	119 [118–120]	433	0.984 [0.983–0.984]
Recirculation filter	New	301 [294–308]	[261–273]	0.119 [0.082–0.142]
Recirculation filter	Used	81.7 [77.1–86.1]	[336–348]	0.761 [0.751–0.767]

Figure 4

Intake and recirculation prefilter particle size efficiency measurements.

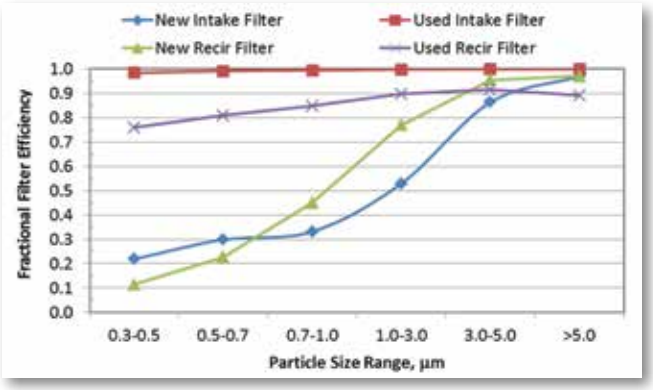
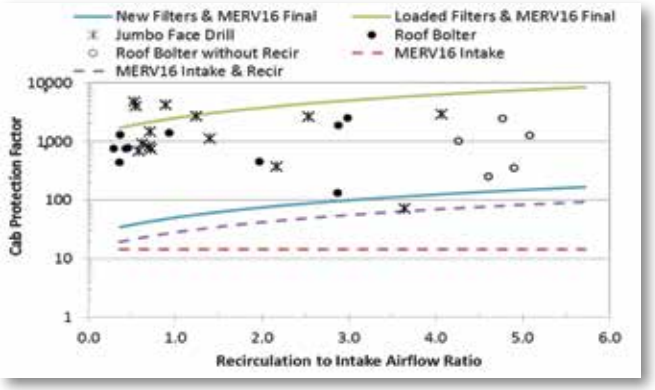


Figure 5

Field-measured protection factors shown with modeled ranges.



lation filters and their respective submicron (0.3-1.0 µm) collection efficiencies measured for modeling cab protection factor performance thresholds during field testing. The intake filter airflow rate tested was similar to the average airflow rate measured on the face drill in the field (Cecala et al., 2012a). The recirculation airflow rates tested were similar to the airflow rates measured within the first few shifts with a new filter and within the last few shifts just before the filter was changed (Cecala et al., 2012a). The particle size collection efficiency characteristics measured for both these unrated intake and recirculation filters used during the field testing are also shown in Fig. 4. As can be seen in this illustration, the filter efficiencies notably increased from the new filter condition to the used (loaded) filter condition. The intake filter collection efficiency for submicron particles (0.3-1.0 µm) increased from 23% to 98% for the new and used filter, respectively. The recirculation filter collection efficiency for submicron particles (0.3-1.0 µm) increased from 12% to 76% for the new and used filter, respectively. These filters were used as prefilters placed upstream of the higher efficiency MERV 16 final filter used in the face drill cab filtration system.

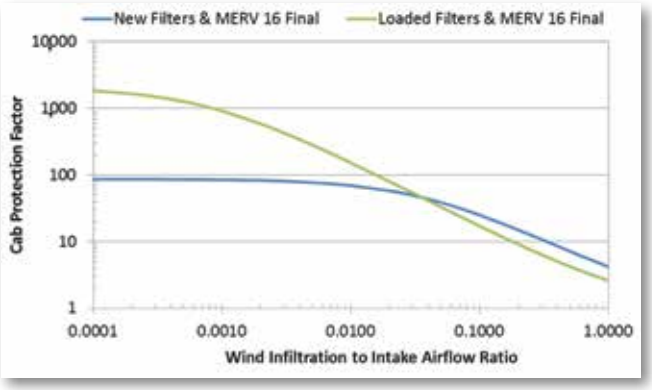
The MERV 16 final filters used on both cab filtration systems and the MERV 16 intake filter used on the pressurizer intake unit of the bolting machine cab were both rated at greater than or equal to 95% collection efficiency on submicron particles (0.3-1.0 µm). For protection factor modeling, these filters will be assumed to be 95% efficient at their new condition and at least 98% efficient in their loaded condition, similar to the loaded intake filter efficiency measured in the laboratory. The only difference between the cab filtration systems tested during field evaluations was that the roof bolter cab had a fan-powered precleaner pressurizer unit with the MERV 16 intake filter, compared to an unpowered intake filter unit with the unrated intake filter used on the face drill cab. The final and recirculation filters used on both cabs were the same throughout most of the field testing, having similar intake and recirculation airflow rates during field testing (Cecala et al., 2012a). After approximately 500 hours of operation, or two thirds of the bolter testing period, the recirculation filter was removed to examine the operational effectiveness of this two-filter system configuration (MERV 16 intake and final filter) when using the pressurizer intake unit (Cecala et al., 2012a). Using the two-filter configuration on the bolting machine dramatically increased its filtration system recirculation airflow rate during the later part of the field tests. The face drill cab testing throughout the field study continued to use the three-filter configuration, because the unpowered intake filter unit only provided negligible intake airflow into the cab with the recirculation filter removed (Cecala et al., 2012a).

Figure 5 shows the cab protection factors measured during the field studies as compared to the expected lower (blue solid) and upper (green solid) operating ranges modeled for the cab filtration systems. The three-filter cab modeled (equation 8) used 119 m^3/hr (70 cfpm) of intake airflow with recirculation airflows ranging between 42.5 and 680 m^3/hr (25 to 400 cfpm), at an assumed 2% (0.02) intake air leak, and with no wind penetration. The assumed 2% (0.02) intake airflow leakage was used for all the field cab modeling because others have considered this figure to be the maximum amount of leakage acceptable for a sufficiently sealed cab filtration system (ASAE, 1997). The lower protection factor model curve was determined with the new intake and recirculation fractional filter efficiencies of 0.23 and 0.12, respectively (Table 1), and a new final filter efficiency of 0.95. The upper protection factor model curve was determined with the used intake and recirculation filter efficiencies of 0.98 and 0.76, respectively (Table 1), and a used final filter efficiency of 0.98. Figure 5 illustrates that 29 out of 33 field protection factor measurements were found to be within the modeled operating ranges (curves) expected from these cab filtration systems. The cab-measured points were spread out between the lower and upper model curves because the filter efficiencies and airflows were changing due to dust loading over the seven-month sampling period (Cecala et al., 2012a). The four outlying points can simply be accounted for by slightly increasing or decreasing the model's filter collection efficiencies by 1 to 2% (0.01 to 0.02) or the intake leakage value by 1 to 2 % (0.01 to 0.02). It is reasonable to expect that these filter efficiencies and leakage values can vary by this much due to filter product variations, filter airflow efficiency variations and diverse dust loading conditions experienced between cabs during mining. Operating the roof bolter filtration system without the recirculation filter (open points in Fig. 5) increased the recirculation-to-intake airflow ratio while maintaining comparable protection factors with the three-filter system. This particular two-filter system arrangement performed well because the high efficiency final filter cleans both the filtered intake air and unfiltered recirculation air.

Finally, a single- and two-filter system (Eqs. (10) and (9)) without a final filter were modeled with their curves also

Figure 6

Detrimental wind infiltration effects from very low to no cab enclosure pressurization.



shown in Fig. 5. The first curve (red dashed) was modeled using only a new MERV 16 rated (95%) intake filter and the second curve (purple dashed) was modeled using both a new MERV 16 rated (95%) intake and recirculation filter. These models used identical airflow and leakage operating conditions as the three-filter systems modeled with a final filter. The single-intake MERV 16 filter model shows a constant protection factor of 14.5 for the recirculation-to-intake airflow ratio range modeled. The two-filter system model illustrates a progressively higher cab protection factor with respect to the recirculation-to-intake airflow ratio as compared to the single-intake filter model. This improvement is a result of the multiplicative filtration of the cab's interior air (Organiscak and Cecala, 2008b). The three-filter system (models and field data) with a MERV 16 final filter was shown to perform better than the single- and two-filter models with MERV 16 filters because the final filter additionally cleans all the air circulated throughout the cab filtration system. Comparing the field data in Fig. 5 to the laboratory data in Fig. 3 shows that the three-filter system with a final filter can outperform a two-filter system without a final filter.

Discussion

The single-, two- and three-filter system models described in this paper are only a few of many that can be developed by using the node analysis technique. In particular, air leakage was only introduced and modeled as outside air bypassing the intake filter. Air leakage around other filters in the system can also be quantified by multiplying the filter penetration $(1 - \eta)$ by the portion of airflow passing through the filter $(1 - I)$, as previously demonstrated for the intake air leakage term in Eq. (3). Intake air leakage was specifically modeled by the authors because contaminant concentrations are usually the highest outside the cab and their leakage around the intake filter would most likely impact the response of the system models. Also, the largest negative pressure differential in the filtration system with respect to atmospheric pressure is usually at the outside intake filter unit, increasing the likelihood of air leakage through the intake circuit of the system. Other filtration system designs can be conceived and modeled by similarly applying these node analysis techniques demonstrated.

Most of the cab filtration modeling exercises described in previous publications and in this paper assume adequate cab enclosure pressurization with no outside wind intrusion into the cab (Cecala et al., 2013; Cecala et al., 2012b; Organiscak and Cecala, 2009). The quantity of wind infiltration into cab enclosures with very low to no pressure is difficult to directly measure and has been previously estimated by defining the operating conditions with orifice airflow exiting the cab being reversed to orifice airflow into the cab (Heitbrink et al., 2000; Organiscak and Cecala, 2008b). This tends to occur when wind air velocity pressure exceeds cab static pressure. Exterior wind infiltration into an enclosure was previously related to the wind velocity pressure and static cab pressure differential across round orifices in an enclosure facing directly into the wind (Heitbrink et al., 2000). Given that wind airflow intrusion through other cab opening configurations (orifice shapes, orientations, shielded, etc.) can be more difficult to predict, and that numerous gaps or holes in cab enclosures are typically concealed, accurate wind airflow quantities infiltrating most cabs would be nearly impossible to determine at very low to no cab pressures. However, a cab with good enclosure integrity can typically be pressurized above wind velocity pressures to ensure that maximum cab protection factor performance of the filtration system can be achieved. A reasonable operating range of cab enclosure pressures is between 12.5 and 62.3 Pa (0.05 and 0.25 in. wg.), which should withstand wind velocity intrusions of 16.4 and 36.5 km/hr (10.2 and 22.7 miles/hr), respectively (Cecala et al., 2013; Cecala et al., 2012b).

Figure 6 illustrates the detrimental effects that wind infiltration into the cab can have on protection factors by modeling a range of wind infiltration-to-intake airflow ratios into the cab enclosure at two particular operating conditions. The cab filtration system modeled was the three-filter system using new and used intake, recirculation and MERV 16 final filters. Table 1 shows the intake and recirculation filter efficiencies and their airflow conditions modeled, assuming a 2% intake airflow leakage. The new and used MERV 16 final filter efficiencies also used in these models were 0.95 and 0.98, respectively. Minimal cab protection factor changes were projected below one-thousandth (0.001) of the wind infiltration to intake airflow ratio into the cab, while noticeable protection factor decreases were projected above this airflow ratio. Although the cab with higher efficiency filters performed notably better than the cab with lower efficiency filters at minimal wind intrusion, its performance deteriorated more rapidly as wind infiltration increased and became worse than the lower efficiency filter cab when the wind infiltration to intake airflow ratio was above 0.03. This noteworthy cab performance change with the higher efficiency filters was a result of the wind infiltration into the cab being filtered at a lower recirculation airflow rate than the cab with the lower efficiency filters. The significant deterioration in cab protection factors illustrated for both cabs above the wind infiltration to intake airflow ratio of 0.1 would likely represent a condition where a door or window would be open. These significant deteriorations in cab performance when doors are opened have been observed and measured in previous field studies (Noll et al., 2010; NIOSH, 2008).

Conclusions

Node analysis modeling techniques were used to describe the performance of cab filtration systems and were verified by laboratory and field testing of these systems. A node diagram of a three-filter system was illustrated with the formulation

of a mathematical model that described the mass concentration balance removed by the cab filtration system and leaving the cab enclosure at steady state conditions. Model variables included filter efficiencies, intake airflow, intake airflow leakage, recirculation airflow and wind infiltration airflow. This three-filter model was further reduced to a two-filtration system model by substituting zero for the final filter in the system and a one-cab filtration system by substituting zeros for the final and recirculation filters in the system. The laboratory cab protection factor performance data for single-filter (intake) and two-filter (intake and recirculation) systems had a good correlation coefficient of 0.995 (significance level < 0.02) with the protection factor performance model of the filter system operating parameters.

For the three-filter model verification of the cab field data collected, new and used intake and recirculation filters had to be laboratory tested to determine their submicron (0.3-1.0 µm) collection efficiencies expected during the field study. Significant increases in submicron particle collection efficiencies were measured between the new and used intake filters tested (23% and 98% efficiency) and the recirculation filters tested (12% and 76% efficiency). The rated submicron (0.3-1.0 µm) collection efficiency of the new MERV 16 intake and final filters were 95% and were assumed to be 98% for the used dust-loaded filters. Nearly 90% of the cab protection factor measurements were between the upper and lower modeled performance operating curves. The few data points observed outside the modeled ranges can be accounted for by slightly increasing or decreasing the filter efficiencies and air leakage variables by 1 to 2%. Thus, the three-filter model reasonably predicted the protection factor operating ranges for the changing filtration system characteristics during the seven-month field study. This three-filter system design also provided superior cab modeling results and robust long-term cab protection factor performance in the field compared to the single- and two-filter systems modeled and studied in the laboratory. ■

Disclosure

The findings and conclusions in this paper are those of the authors and do not necessarily represent the views of the National Institute for Occupational Safety and Health. Mention of any company name, product or software does not constitute endorsement by NIOSH.

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Investigating use of aggregated data: Does it compromise information gleaning?

by D. Arku and R. Ganguli

Abstract ■ The increased use of sensors to facilitate automation has led to an explosion of data. As data sets grow in size, their use becomes more complex. Therefore, there is an incentive for reducing the size of the datasets, as long as this does not compromise information gleaning. With this in mind, this project explored basic aggregation as a viable alternative to amassing large amounts of data. The goal of the project was to determine if one would arrive at different conclusions had they analyzed aggregated data instead of raw data. In a mine, operational data is typically used for tracking process statistics, correlation between factors, autocorrelation and multivariate models (for a factor of choice). Therefore, this project compared results from such analyses when it was conducted with aggregated data (AD) with the results of analyses conducted with raw data (RD). The data consisted of one-minute-apart readings from a semi-autogenous grinding (SAG) mill on the horsepower, feed rate (tons per hour), rotations per minute (rpm), noise, recycle (tons per hour), density (% solids) and bearing pressure (psig). This data was aggregated by averaging five and 10 continuous (one-minute) observations. Changes in statistical measures between the two approaches were typically within 5% of each other. Differences in correlation coefficients between RD and AD(s) were also within this range. Autocorrelations present within RD were preserved in AD, as long as the time lags were scaled for the amount of aggregation. Regression and neural network models were also developed for power consumption. The prediction performance of developed models was similar whether one used raw data or aggregated data. Overall, it appeared that aggregating the data based on 5- or 10-minute time spans would not have resulted in conclusions (from simple or complex analyses) being different from using raw data. In other words, whether one had used raw data or aggregated data, the conclusions would have been the same, suggesting that time domain aggregation, a common industry practice, is a good alternative to storing high-density data in this case.

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Introduction

Increased automation and process monitoring in the mining industry has led to an explosion of data. However, maximum utilization of the data requires analyses of the data, which can be very challenging for large data sets. Often, the data is not examined, as an operator is unwilling to take the time to allocate resources for truthing and analysis. Therefore, there is an incentive to compress or aggregate data, as long as that does not result in loss of information.

This paper explored the feasibility of data aggregation using operations data of a semiautogenous grinding (SAG) mill in a gold mine in Alaska.

D. Arku and R. Ganguli, members SME, are mining engineer at Freeport-McMoRan, Morenci, AZ and professor of mining engineering at the University of Alaska Fairbanks, AK, respectively. **Paper number TP-13-039. Original manuscript submitted July 2013. Revised manuscript accepted for publication January 2014. Discussion of this peer-reviewed and approved paper is invited and must be submitted to SME Publications by Sept. 30, 2014.**

The project

Typical analyses done with operational data include time trends of parameters and interrelationships between parameters. Techniques include tracking process statistics (average and standard deviation), analysis of variance, autocorrelation, multivariate regression modeling and nonlinear modeling (such as neural networks) relating a set of parameters to another.

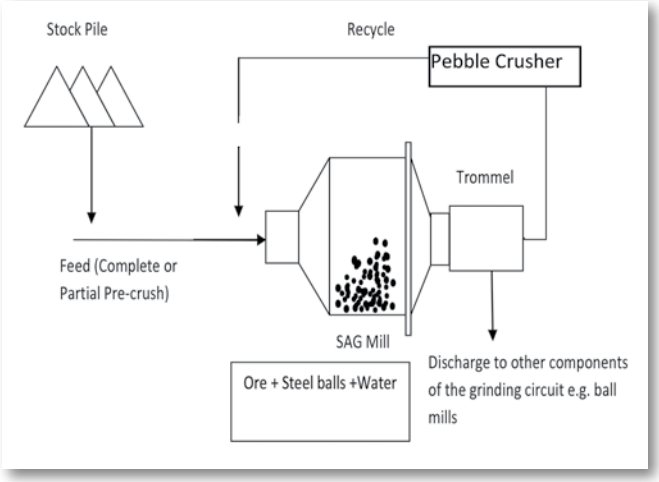
The purpose of the project was to explore if one would be misled about important aspects of the process (as indicated by the above mentioned analyses) if aggregated data was used instead of raw data.

Project design

Data from a 13-MW SAG mill operation, installed at a gold mine in Alaska, was used in this project. Figure 1 depicts the relevant portions of the SAG mill circuit.

Figure 1

Simplified SAG mill circuit.



Given high electricity costs in Alaska, a key goal was to identify factors that contributed to high power consumption in the SAG mill. Therefore, this study was conducted keeping in mind that any analyses conducted by the engineers would be for understanding power consumption. The operating parameters of the SAG mill considered critical to understanding the power consumption were (according to the mill engineers):

- SAG rpm: Speed of the rotation of drum/mill.
- Bearing pressure: Depends on the weight of the drum, with changes indicating changes in mill charge (contents of the drum).
- Density (% solids): Related to the contents of the drum (the ore and water).
- Noise: This refers to the noise emanating from the mill as a result of the tumbling effect and impact on liners. It could be related to the content of the mill and the viscosity of the water.
- New feed (tph): Rate of fresh material (ore) being fed into the mill.
- Recycle (tph): Pebble crusher product to be fed back into the system for further grinding.

The data consisted of 1-min (apart) readings on the horsepower, feed rate (tons per hour), rotations per minute (rpm), noise, recycle (tons per hour), density (% solids) and bearing pressure (psig) covering a continuous timespan of 20,120 minutes.

Methodology

Data was aggregated by averaging the 1-min readings over two time spans, 5 min and 10 min. This resulted in three distinct data sets, the raw data (1-min span), aggregated data 5 (AD5; 5-min averages) and aggregated data 10 (AD10; 10-min averages). The averages were not rolling; i.e. the time span in one average did not overlap with the next average. For example, while there were 10 rows of raw data (RD) for a 10-min time span, there were only two rows in the AD5 version and one row in AD10 version. Figure 2 plots the horsepower (HP) in raw form.

Data can be aggregated based on various criteria such as time domain (length of time) and variability within the data. Time domain aggregation was chosen not only because of simplicity, but also because it is a common industry practice.

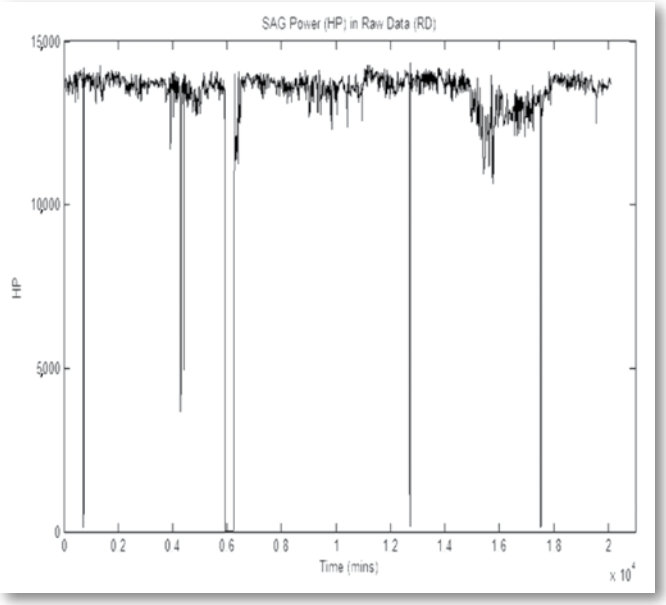
Table 1

Number of observations.

Subset	Raw data (RD)	Aggregated data 5 (AD5)	Aggregated data 10 (AD10)
s1	723	144	72
s2	3,569	713	356
s3	108	21	10
s4	1,513	302	151
s5	6,463	1,292	646
s6	4,786	958	479
s7	2,593	518	259

Figure 2

SAG power (HP) of raw data (RD).



Other methods will be explored in the future. The time span to aggregate was kept short to ensure maximum likelihood of success (the exact time span choice was arbitrary).

In addition, the raw data was further segregated into subsets based on periods of instability in horsepower (HP) readings. This was done to ensure that temporary periods of instability, when process values changed significantly and rapidly, did not corrupt steady state analysis. A subset was a steady state region between two periods of instability. Seven (7) subsets were derived and used in this work, with subset 3 being very small. A summary of the number of observations before and after aggregation is given in Table 1.

The raw and aggregated data were then subjected to basic analyses (statistical measures, correlations, linear regression) and complex analyses (neural network modeling). The conclusions from the analyses on raw data (RD) were then compared to conclusions obtained from aggregated data (AD) to determine if aggregation of data resulted in different conclusions.

Basic analyses

Mean and standard deviation analysis. Differences in standard deviation and average values (expressed as percentages) between fields in RD and AD categories are given in Tables 2 and 3. As can be seen in Table 2, there was a difference of -0.06% between the average of 'New Feed' (RD) and the average of 'New Feed' (AD5) in subset 2. Since AD is obtained by averaging rows of RD, there should be no real difference in the averages of the subsets. Therefore, Table 2 is not a surprise. Though not shown, the results are the same for AD10. About 98% of the values fell within a change of less than 1%. Similarly, given their origin, the standard deviations of AD should be less than that of RD. This is also as seen in the results. Subset 3, being very small, shows a high difference. Otherwise, a large majority of the standard deviations for aggregated data were within 10% of that of raw data.

Analysis of variance (ANOVA). ANOVA was carried out to test whether there were statistical differences between group means of the derived aggregated data (ADs) and the original raw data. The groups were the variables (fields) in the data. This test showed that there was no statistical difference between the means in a field between raw and aggregated versions. The results are not shown due to space constraints.

Correlation coefficient (*r*). Correlation coefficient (r) is a measure of relationship between variables. Tables 4-6 show the correlation coefficient between factors when computed using RD, AD5 and AD10 using subset 5.

The correlation coefficients between two fields (say HP versus recycle) may be different in different subsets. For example, the correlation coefficient of 0.63 between HP and BP using RD on subset 5 in Table 4 is different from the correlation coefficient of 0.33 between HP and BP in RD in subset 1 (not shown). However, the correlation coefficient between two fields in a subset 5 are close to each other, no matter the level of aggregation (RD, AD5 or AD10). For example, the correlation coefficient between HP and BP is 0.63, 0.65 and 0.67 for RD, AD5 and AD10 in subset 5.

Though not shown for reasons of space, the results from other subsets lead to similar conclusions. Generally

Table 2

Percentage change in averages between RD and AD5 subsets.

Subset	HP	Recycle	BP	New feed	Noise	Density	rpm
s1	0.01	0.09	0	0.01	-0.13	0.02	0.21
s2	-0.01	-0.01	0	-0.06	-0.01	-0.01	-0.06
s3	-0.03	0	-0.02	-2.64	-0.25	-0.36	-0.06
s4	0	0.03	0	-0.16	-0.01	0.01	-0.15
s5	0	0	0	0	-0.02	0	-0.09
s6	0	0.01	0	0.08	0.02	0.01	0.01
s7	0	0.01	0	0.01	-0.05	0	0.22
All	0	0	0	0	0	0	-0.01

Table 3

Percentage change in standard deviation between RD and AD5 subsets.

Subset	HP	Recycle	BP	New feed	Noise	Density	rpm
s1	-2.04	-0.88	-3.18	-2.15	-0.48	-1.23	-54.66
s2	-6.15	-0.69	-2.43	-1.58	-0.16	-1.86	-18.48
s3	-36.92	-13.53	-9.35	-65.98	-5.85	-73.06	-71.11
s4	-2.05	-1.23	-1.99	-11	-0.63	-1.91	-0.32
s5	-0.72	-0.89	-1.35	-2.55	-0.42	-0.74	-0.09
s6	-0.54	-0.72	-0.27	0.18	-0.4	-1.01	-1.53
s7	-2.59	-0.73	-1.15	-1.67	-0.82	-2.94	-2.72
All	-0.63	-0.61	-0.48	-0.94	-0.2	-1.83	-0.63

Table 4

Correlation coefficient between fields for RD in subset 5.

	HP	Recycle	BP	New feed	Noise	Density	rpm
HP	1.00	0.35	0.63	0.36	-0.10	0.18	0.76
Recycle	0.35	1.00	0.27	0.55	-0.74	0.15	0.49
BP	0.63	0.27	1.00	0.08	0.05	-0.05	0.53
New feed	0.36	0.55	0.08	1.00	-0.65	0.52	0.35
Noise	-0.10	-0.74	0.05	-0.65	1.00	-0.45	-0.20
Density	0.18	0.15	-0.05	0.52	-0.45	1.00	0.22
rpm	0.76	0.49	0.53	0.35	-0.20	0.22	1.00

speaking, correlation coefficients (r) changed by no more than 5% in all cases with AD5. About 90% of all change fell within the 5% tolerable limit with AD10.

The difference in r between RD, AD5 and AD10 was greater when the subsets were smaller. This can be seen in Tables 7 and 8, which show the difference between RD and AD5 for subsets 2 (smaller) and 5 (larger).

One must be careful when examining the difference in correlation. When two factors are not really correlated (r is ~0), minor differences in correlation get exaggerated when expressed in percentage. Thus, a difference in r of –0.0101 shows up as a 264.3% difference in Table 7, since the base r (HP versus recycle for RD, subset 2) is -0.003.

Independence lag: Derived from autocorrelation. In many processes, samples obtained within a certain time interval are correlated (i.e. the process is auto-correlated). For example, the viscosity of a fluid in a tank may not change much from one minute to the next. In these processes, samples are independent only if they are taken certain time intervals (or "lags") apart. This time interval or time to achieve independence has been termed independence lag (IL) in this paper. Figure 3 presents the variation in autocorrelation with time lag for some of the fields. For example, in Fig. 3, the autocorrelation factor (ACF) for HP drops to 0.4 at a time lag of 200. The ACF for a field was the correlation between samples that are a given lag apart.

Figure 3 shows that ACF is preserved with aggregation, as long as one accounted for the aggregation. For example, HP values achieve a ACF of 0.3 for a time lag of 200 minutes (for RD data). When the ACF is computed using AD10 data, the same ACF (0.3) is observed at lag 20. Since each row in AD10 is 10 minutes apart, lag 20 represents data that is 200 minutes apart. Thus, the results show that ACF is preserved, though at a time scale determined by the level of aggregation.

Representing the ACF at lag L and level of aggregation a, as

$$\phi_L^a$$

the example can be elegantly represented as follows:

$$\phi^{1}_{(200/1)} = \phi^{5}_{(200/5)} = \phi^{10}_{(200/10)}$$

Note that a is 1 for RD and 5 for AD5, and 10 for AD10. Or generically:

$$\phi_L^a = \phi_{L/i/a}^i \quad (1)$$

represents the conservation of the ACF as the data undergoes an aggregation of i/a, for i greater than a. In other words, the ACF observed in lag L for level of aggregation a can be expected to be the same as the ACF at lag i/a for data aggregated at a level i.

The results for other factors are similar to what is shown in Fig. 3.

Table 5

Correlation coefficient between fields for AD5 in subset 5.

	HP	Recycle	BP	New feed	Noise	Density	rpm
HP	1.00	0.36	0.65	0.37	-0.11	0.18	0.77
Recycle	0.36	1.00	0.27	0.58	-0.74	0.15	0.50
BP	0.65	0.27	1.00	0.09	0.05	-0.05	0.54
New feed	0.37	0.58	0.09	1.00	-0.67	0.53	0.36
Noise	-0.11	-0.74	0.05	-0.67	1.00	-0.46	-0.20
Density	0.18	0.15	-0.05	0.53	-0.46	1.00	0.22
rpm	0.77	0.50	0.54	0.36	-0.20	0.22	1.00

Table 6

Correlation coefficient between fields for AD10 in subset 5.

	HP	Recycle	BP	New feed	Noise	Density	rpm
HP	1.00	0.38	0.67	0.37	-0.11	0.18	0.77
Recycle	0.38	1.00	0.27	0.60	-0.75	0.17	0.51
BP	0.67	0.27	1.00	0.11	0.06	-0.05	0.55
New feed	0.37	0.60	0.11	1.00	-0.69	0.54	0.36
Noise	-0.11	-0.75	0.06	-0.69	1.00	-0.47	-0.20
Density	0.18	0.17	-0.05	0.54	-0.47	1.00	0.23
rpm	0.77	0.51	0.55	0.36	-0.20	0.23	1.00

Table 7

Difference in correlation coefficient between RD and AD5 (expressed in %) in subset 2.

	HP	Recycle	BP	New feed	Noise	Density	rpm
HP	0.00	264.29	1.06	-23.62	69.13	-14.00	-23.61
Recycle	264.3	0.00	1.62	2.28	0.85	1.82	14.21
BP	1.06	1.62	0.00	1.74	3.40	-2.39	-13.08
New feed	-23.62	2.28	1.74	0.00	2.06	1.16	-6.06
Noise	69.13	0.85	3.40	2.06	0.00	2.32	43.91
Density	-14.00	1.82	-2.39	1.16	2.32	0.00	19.40
rpm	-23.61	14.21	-13.08	-6.06	43.91	19.40	0.00

Table 8

Difference in correlation coefficient between RD and AD5 (expressed in %) in subset 5.

	HP	Recycle	BP	New feed	Noise	Density	rpm
HP	0.00	2.17	2.19	2.77	2.66	0.58	1.09
Recycle	2.17	0.00	0.73	4.47	0.68	3.46	2.27
BP	2.19	0.73	0.00	18.28	2.75	-4.98	1.72
New feed	2.77	4.47	18.28	0.00	3.22	2.71	2.45
Noise	2.66	0.68	2.75	3.22	0.00	1.41	1.91
Density	0.58	3.46	-4.98	2.71	1.41	0.00	2.62
rpm	1.09	2.27	1.72	2.45	1.91	2.62	0.00

Advanced analysis: Horsepower modeling

Two standard approaches to modeling the horsepower consumption, linear regression and neural networks, were examined and are briefly discussed in this section. In both cases, a model was developed for horsepower using the six other parameters. Modeling performance was measured based on horsepower predictions, i.e., coefficient of determination (*R*-squares) and root mean square error (RMSE) of the predictions from the resultant models.

Regression model for horsepower. Tables 9 and 10 summarize the regression model performances for the various subsets. One can see that whether it was R-square (Table 9), or RMSE (Table 10), the performance was similar for RD, and AD5 and AD10, in all subsets except subset 3. Subset 3 was very small and, therefore, should not be counted. In other words, whether one used raw data or aggregated data for developing regression models for horsepower, they would be able to use the developed model to make predictions that were similarly accurate.

RMSE, however, slightly improved with aggregation. This is not surprising. With increasing aggregation, the data swings around less wildly, reducing the margin of error.

Neural networks (NN). Neural networks, a popular nonlinear modeling technique, has been used to model milling data (Ganguli et al., 2006; Hales et al., 1992). Therefore, it was natural to examine the effect of data aggregation on nonlinear modeling based conclusions.

Data for neural network (NN) modeling: Subsetting. Data for NN modeling are usually split into training, calibra-

Figure 3

Correlograms for three variables (horsepower (HP), bearing pressure (BP) and density) in RD and ADs of entire data sets.

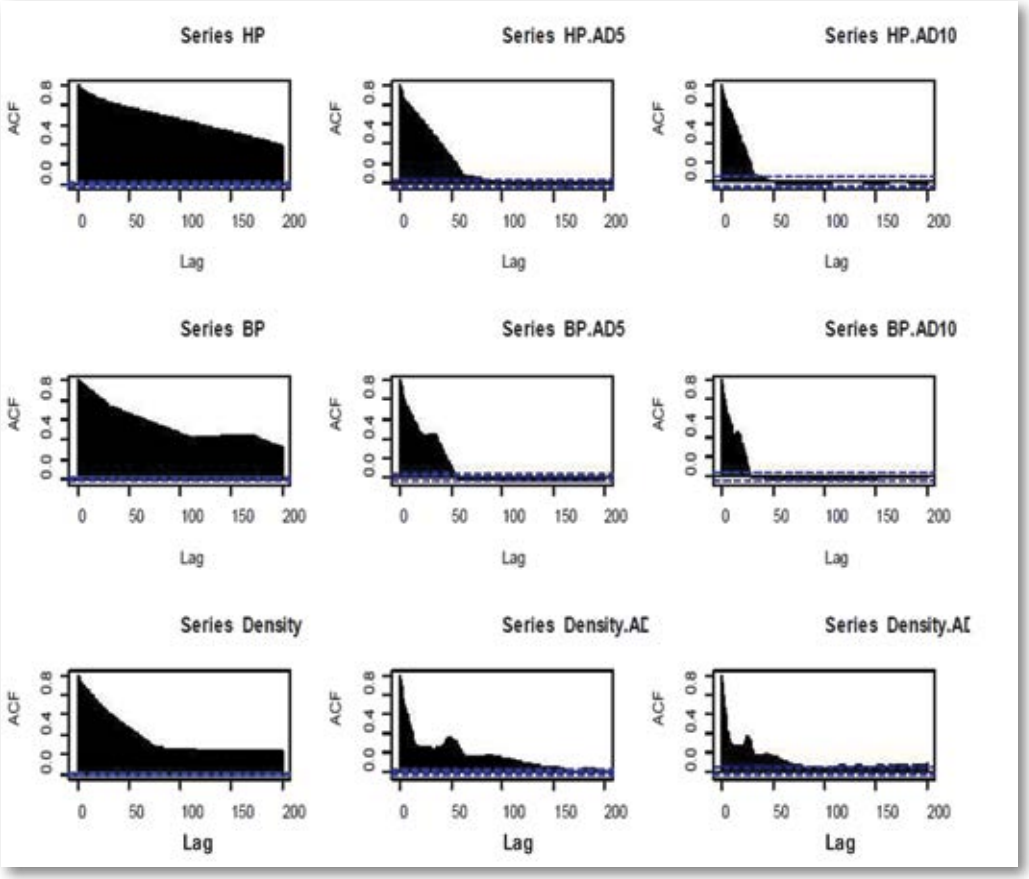


Table 9

Summary of model performance (*R*-square) from linear regression (model with all six variables) on data subsets.

Data subset index	RD	AD5	AD10
1	0.38	0.40	0.45
2	0.46	0.45	0.50
3	0.71	0.91	0.96
4	0.59	0.59	0.61
5	0.68	0.70	0.72
6	0.89	0.87	0.90
7	0.54	0.59	0.61

Table 10

Summary of model performance (RMSE) from linear regression (model with all six variables) on data subsets.

Data subset index	RD	AD5	AD10
1	142.90	140.40	129.30
2	174.60	164.50	151.60
3	213.60	89.01	67.40
4	200.20	198.60	186.50
5	223.30	216.30	207.10
6	222.50	212.20	206.10
7	161.20	148.60	141.90

Table 11

NN performance (R^2) for various subsets.

	Subset index	RD	AD5	AD10
All	S1	0.961	0.947	0.930
	S2	0.910	0.920	0.913
	S3	0.990	NA	NA
	S4	0.936	0.928	0.951
	S5	0.921	0.930	0.937
	S6	0.981	0.983	0.983
	S7	0.933	0.929	0.919

Table 12

NN performance (RMSE) for various subsets.

	Subset index	RD	AD5	AD10
All	S1	49.975	59.590	61.330
	S2	102.770	87.692	86.870
	S3	63.618	NA	NA
	S4	110.550	115.200	90.590
	S5	154.331	144.120	135.540
	S6	129.240	122.420	121.520
	S7	85.102	85.337	90.690

tion and prediction subsets according to a predefined ratio (say, 60, 20, 20). The training subset is used in the training phase of the modeling process and is, therefore, the largest subset. The calibration subset is used to determine when to stop training. The prediction subset is used to ultimately test the developed model. Thus, to develop a neural network model for "subset 1" (see Table 1), one has the split the 723 rows of raw data (or 72 rows of AD10) into three parts. The reader is referred to Ganguli et al. (2011) for a quick primer on neural network modeling.

As with the regression models, the performance metrics used were the R^2 value of predictions (Table 11), and the RMSE (Table 12). As can be seen, there is no real difference with regard to modeling ability, whether one used raw data or aggregated data. Though not shown, no difference was seen between RD and AD for training subsets, calibration subsets and prediction subsets. The 'All' in Tables 11 and 12 refers to an entire subset, i.e., when you included training, calibration and testing in determining the performance. RMSE's are also similar for a given subset whether one used RD or AD. Note that horsepower values are in the 13,000 range and, therefore, a difference in RMSE of 30 or 40 is not that big.

Conclusions

The paper showed that when 1-min-apart SAG mill operational data was aggregated into 5-min and 10-min averages, and used for analyses, conclusions reached when using aggregated data were similar to those using raw data. In other words, there was no harm in aggregating data from an analytical perspective. Specifically:

1. Process averages were almost identical.
2. Process standard deviations were slightly reduced with aggregation.
3. Correlation between factors were similar whether one used RD or AD, though occasional differences were seen for smaller subsets.
4. Autocorrelation in RD was preserved in AD. The independence lag could be linearly scaled based on level of aggregation.
5. Multivariate regression models performed the same whether one used RD or AD.
6. Neural network models performed the same whether one used RD or AD. ■

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MEC produces new video: "Iron in Our Electrical World"

The Minerals Education Coalition has just released "Iron in Our Electrical World," a 19-minute video that can be viewed at www.mineralseducationcoalition.org/videos. This video, the second in the MEC's Minerals in Our Electrical World series, will be a vital resource for high school teachers and students, as well as informative and entertaining for all others with an interest in science. The world of electricity is highly dependent on iron, from small computers to mega-sized motors.



Through onsite filming and specially designed graphics, the content has been created to help teachers in the disciplines of chemistry, geology, and electrical and mechanical engineering. Viewers will learn about iron formations and the extraction and processing of iron ore. They will also view exciting demonstrations of applied electricity, which include an octocopter for aerial photography, a Tesla sports car, a guitar and amplifier, a roller coaster and many other products.



Rennie Kaunda, PE, consulting civil and mining geotechnical engineer, narrates a portion of the new video.

Vivid graphics highlight the electromagnetic properties of iron, which are explained by expert geologists and mining, mechanical and electrical engineers. MEC thanks Cliffs Natural Resources for supporting the "Iron in Our Electrical World" video and allowing onsite filming at its facilities. ■

Hands and minds on science: MEC attends the USA Science and Engineering Festival

All aspects of STEM (Science, Technology, Engineering and Mathematics) programs attracted nearly 325,000 attendees to the Washington, D.C. Convention Center on April 24-27, 2014. With the assistance of SME volunteers, the Minerals Education Coalition (MEC) conducted educational activities for children and adults about the electrical conductivity of minerals, as well as the importance of minerals and mining in our everyday lives. Many young people enjoyed trying on miners' personal protection equipment, as they considered what it might be like to work in the mining industry.

Thanks to our expert SME volunteers — Lee Bray, Mike Kaas, Florence Katrivanos, Vlad Kecojevic, Mike Korb, Patricia Korb, Karen Lucas, John Lucas, Camah Mulabah and Lin Shi. Their commitment made this MEC outreach effort truly successful. ■



SME member Mike Korb (c) watches two young visitors to the MEC exhibit try on miners safety gear.

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Young Leaders Committee

From research to rule: Understanding the regulatory process

by David Chirdon, MSHA

Throughout the year, the SME Young Leaders Committee invites an established member of the mining industry to provide mentorship to its members across a variety of topics. The most recent mentor was David Chirdon with the Mine Safety and Health Administration. Chirdon received a B.S. in engineering of mines in 1981 from West Virginia University and has worked for the Mine Safety and Health Administration (MSHA), Approval and Certification Center since 1983. He spent the first 10 years of his career performing approval evaluations of explosion-proof enclosures, underground mining machines and longwall mining systems.



CHIRDON

From 1994 through 1997, Chirdon supervised the Intrinsic Safety and Instrumentation Branch and, from 1998 through 2008, he was chief of the Electrical Safety Division. He was the coordinator of the MSHA effort to develop proximity detection, chairing the committee that promulgated the 30 CFR Part 6 regulation that permits MSHA to approve equipment tested by independent laboratories or equipment designed to international standards. He also chaired the MSHA Communications and Tracking Committee. He is currently the program manager for new product development and the team leader for the rulemaking to require proximity detection systems on underground mining machines. He is a 30-year member of SME.

According to Joshua Chlopek, YLC member, "In only an hour, Chirdon brought clarity to the rulemaking process that really hit home with the Young Leaders. (He) created an intriguing and engaging interaction that included relatable examples, encouraged industry participation in the rulemaking process and highlighted when and how industry can get involved."

Chirdon's comments to the YLC

First things first, find out what MSHA has on its radar for rulemaking. It's publically posted for your convenience and is referenced as MSHA's regulatory agenda, www.msha.gov/regsinf1.htm. MSHA determines its agenda from stakeholder input and existing and emerging health and safety research.

Rulemaking touches the industry in a lot of different ways, so MSHA develops a rulemaking committee for every item on its regulatory agenda. Each committee consists of an economist, technical representative, enforcement representative, regulatory specialist and an attorney.

Rulemaking is a long process that considers a lot of factors. It may be on MSHA's regulatory agenda, but that doesn't mean now is the right time to engage. So, when is the right time to engage? You need to get familiar with the steps to the rulemaking process and how MSHA communicates this information to the industry and public.

The *Federal Register* is the website where all the rulemaking activities are posted. You can keep track of all the steps in MSHA's rulemaking process here, www.federalregister.gov/agencies/mine-safety-and-health-administration. MSHA may solicit the public for input in advance of any rulemaking. This solicitation occurs when MSHA posts a request for information or advanced notice of proposed rulemaking in the *Federal Register*. This step of the process is at the discretion of the rulemaking agency and is only used when MSHA determines that the process could benefit from advance public input. This is your first of three opportunities to voice your opinion about a rule being promulgated by MSHA.

After receiving input from the public, MSHA establishes a rulemaking committee that evaluates the input provided by the public and develops a proposed rule which is then posted on the *Federal Register* for public review allowing a set period of time where comments can be made. This is known as the comment period and is a great opportunity to formally voice your concerns or support for any and all parts of the proposed rule. MSHA's final rule must address any comments submitted through this process. At times, MSHA may also choose to conduct public hearings to obtain more input from stakeholders.

According to Chirdon, these public hearings are an opportunity for your voice to be heard. Any person is permitted to present information related to the proposed rule. You could present data collected by your company, consultants or introduce research that supports your position. Just like comments submitted through the *Federal Register* during the comment period, MSHA's final rule must address any information introduced at the public hearings.

You and your company have two or three separate opportunities to affect the content of an MSHA rule, but you should keep these rulemaking considerations in mind when you prepare those comments: economic analysis, cost/benefit analysis and ex parte communications. The rulemaking committee reviews and addresses all comments received. It is critical that supporting data be submitted with the comments to allow MSHA the opportunity to appropriately and adequately adjust the requirements defined by the final rule. Working cooperatively with MSHA by providing realistic, field-testing environments, you can help ensure all comments are fully appreciated and addressed. Proximity detection systems are a great example of this cooperative approach.

Armed with this research and after addressing all comments, the final rule is drafted and reviewed by MSHA, the Department of Labor, the Office of Management and Budget, and sometimes even Congress, before being posted in the *Federal Register*. ■

Robert S. Shoemaker

The man behind a $1-million commitment to SMEF

By AnnMarie Kochevar, SME Foundation Manager

On April 14, 2014, the SME Foundation (SMEF) received confirmation from Robert S. Shoemaker, 1978 SME President and an SME member since 1952, that he will give $1 million to support Ph.D. grants and general Foundation activities. "It gives me great pleasure to be able to support the SME through this gift, said Shoemaker. It has been an honor to be a member of the SME throughout my career and to be able to be a part of the great work that the organization is doing."



SHOEMAKER

Shoemaker's gift will be realized at the rate of $100,000 per year, with the balance payable upon his death. The Foundation Trustees and SME members are truly grateful for his tremendous support and loyalty to the Society. He is leaving a wonderful legacy.

Shoemaker is a self-made man. He started on the path toward his successful career after returning from a tour of duty during World War II. After receiving bachelor's and master's degrees in inorganic chemistry at Oregon State College, he went on to earn a second master's degree in metallurgical engineering at the University of Wisconsin in 1953. Finally, in 1975, Shoemaker was awarded the degree of metallurgical engineer honoris causa from the Montana College of Mineral Science and Engineering.

Shoemaker started his career involved in mineral research and plant operations at Union Carbide Research Laboratories in Niagara Falls, NY and Carbide Metals Co. at its four electrometallurgical plants. In 1962, he joined Bechtel Corp.'s Mining and Metals Division as a supervising engineer. He moved up the ranks during his 19 years with Bechtel and eventually became manager of plant design for its mining and metals division offices in San Francisco, Toronto and Melbourne. After leaving Bechtel in 1981, Shoemaker opened his own consulting firm. He now enjoys retirement and is the docent at the North Star Mining Museum in Grass Valley, CA.

In 1978, while SME President, Shoemaker was asked how the Society could be strengthened to be a more effective professional organization. His response was that members must maintain their professionalism through professional registration and continuing education. "To fulfill this charge, each of us must contribute more of ourselves to our Society."

Shoemaker certainly took his charge personally and has continued to participate in Society activities. "By speaking from our technical experience, SME members can translate technology to the lay public so that they will be informed legislators and voters," said Shoemaker in his 1978 presidential interview in *Mining Engineering* magazine. Now,

(Continued on page 72)



David Kanagy (l) thanks Robert Shoemaker (r) for his donation to the SMEF.

Use AmazonSmile to support the SME Foundation

AmazonSmile (AS) is a website operated by Amazon that lets customers enjoy the same selection of products, low prices and convenient shopping features as they do on Amazon.com. The difference is that when customers shop on smile.amazon.com, the AS Foundation will donate 0.5 percent of the price of eligible purchases to the charitable organization selected.

SME members, family and friends are encouraged to select the SME Foundation to support. There are no extra charges to you, the customer. The donation comes directly from the AS Foundation.

Visit AmazonSmile today and help the SME Foundation receive contributions while you shop. If you need any assistance in setting up your AmazonSmile account, please contact the SME Foundation staff at 303-948-4239. ■



Coming soon:
A new *Mineral Processing Handbook*

by Mark K. Jorgensen, MPD Secretary/Treasurer

In 1985, the SME Mineral Processing Handbook was published in two volumes. I was very happy to part with the $100 it took to buy the books. It was a wealth of information and has steered me in the right direction for much of my career.

But 1985 was a long time ago. It was at least five jobs, four children, four homes and two surgeries ago. Fortunately, the same wife has always been around. Likewise, the industry has changed, and there have been some significant advances.

Today, new process engineers would have a tough time explaining why a rod mill would need to be untangled or why a screw classifier would need new shoes. Sometimes I even wonder if I can remember, it's been so long. New technology has replaced many of the processes that once were common.

The handbook needs to be updated

SAG mills have grown from 8 to 13 m (32 to 42 ft) in diameter and from 5,966 to 29,828 kW (8,000 to 40,000 hp). Gravity concentration has progressed from jigs, spirals and tables to continuous high-speed bowls. In fact, there are processes that take advantage of properties other than hydrophobicity, density, magnetism, electrical conductivity, leaching, ion exchange and SX/EW. It is time.

The new handbook will again be two volumes. As with the first handbook, volume 1 will be devoted to mineral processing. For the first time, volume 2 will be devoted to extractive metallurgy. You will still be able to find much of the same information.

Courtney Young, professor at Montana Tech, explained, "It is not so much of a rewrite, as it is adding the new technology that has been developed."

S. Komar Kawatra, professor at Michigan Tech, also offered that, for both volumes, "There are more than 200 authors. It's a lot of work to get everyone to finish their portion of the work and get it done on time for editing."

The new handbook will be available in digital format, making it searchable, and, of course, more portable. Faster access to information will allow us to make mistakes in real time. SME will own the copyright, which will make it easy for members to copy and use.

When will the handbook be ready?

The goal is to finish the initial input by the end of the summer. Editing will likely take another year, with another undermined amount of time for formatting and publishing. A final publish date will likely not be before February 2016.

If you have any suggestions for content, please contact either Young at Montana Tech for Volume 1 or Kawatra at Michigan Tech for input into Volume 2. You could be a part of metallurgical history. You could buy five copies for your mother.

In the meantime, you can buy the 1985 two-volume set in hardcover on Amazon (or AmazonSmile, see page 69) for $600. Probably one of the few investments I have made that has actually gone up in value. ■

Membership

Jesus Astuvilca, Callao, Peru
Thomas M. Bamford, Barrie, ON, Canada
Jerry Bantz, Livonia, MI
Tyer J. Branca, Hermitage, PA
Ethan E. Brown, Aliquippa, PA
Jonathon Brown, Dublin, CA
Emily E. Bucha, Volant, PA
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Minnick Casey, Seattle, WA
Lindsay E. Chasten, Lead, SD
Dominic Chretien, Charlotte, NC
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Gregory L. Easson, University, MS
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Chase Stevens, Ely, NV
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Ben H. Updegrave, Reno, PA
John A. Versfelt, New Westminster, BC, Canada
George Wozencraft, Houston, TX
Max T. Zimmerman, Slippery Rock, PA
Kelly Zipsie, Overland Park, KS ■

Colorado Section Lifetime Achievement Award to Karen Jass

The Colorado Section of SME presented Karen Jass with the section's Lifetime Achievement Award at its meeting on May 15, 2014. Jass has been an energetic member of SME and the Colorado mining community since 1987, when she started working with the GEM Committee to share mining's mission with the public. She was the GEM Subsection chair from 1996 and 2000 and has remained an active member of the group. She became a Colorado Section board member soon after. She took on the treasurer's job between 2005 and 2008 and served as the section chair from 2008 and 2010. She has remained on the SME Colorado Section board as the past chair for the last four years.

While on the SME Board, Jass converted the newsletter to electronic format, and then she created the section's first website. She also worked to establisg a line item in the SME budget for minerals education outreach through the GEM Committee. Jass worked with Lee Rice to have the GEM Committee participate in the Colorado State Science & Engineering Fair as special judges, giving out awards funded by GEM and SME to projects in the earth sciences. She also chaired the 1997 and 2007 National Science Teacher Association (NSTA) GEM Committee booth, raised funds for the 2014 event and spent hours making and distributing mineral kits.

Jass' participation in mining industry organizations has not been limited to SME. She assumed leadership roles in Women in Mining (WIM) at the state and national levels. Like SME, WIM benefitted from her energy as secretary, treasurer and president. She converted the state and national newsletters to electronic format and distribution. As



Karen Jass has staffed many exhibits educating the public about mining and minerals.

national president of WIM, she worked with the chapter presidents of the first two student chapters writing drafts of bylaws. She set up field trips for the national meetings and has been a major organizer of the last three national meetings held in Colorado.

Jass has also been a member of the Denver Coal Club for about 10 years and inaugurated its first website about the same time as the Colorado Section's website. She was nominated and selected in 2006 to the Mining & Metallurgical Society of America, where she has been working on the educational outreach sections of the MMSA's website with Betty Gibbs. She encourages everyone to share their knowledge of mining and the role that minerals play in our lives whenever possible. ■

Colorado Section golf tournament raises scholarship funds

The annual Colorado Section golf outing, sponsored by Newmont Mining and Resource Capital Funds (RCF), will be held Sept. 5, 2014, at the Fossil Trace Golf Course in Golden, CO. The tournament will have a 1 p.m., shotgun start and a dinner afterwards. Thanks to Newmont and RCF, fees have not increased for several years, but the section is still looking for additional sponsors. The cost is $175 per person or $650 per foursome. All details will be on the Colorado Section webpage of the SME website, www.smenet.org. Contact Lori Freemire, 303-513-2963, lorifreemire@missionroi.com or Jacki Malone, 720-339-7719, jmalone@aquionix.com, for more information. ■

Personal news

SEAN K. McLANAHAN has been named chief executive officer of McLanahan Corp. **MICHAEL W. McLANAHAN** (SME) continues as chairman of the board, while **GEORGE L. SIDNEY JR**. (SME) remains president and chief operating officer. Together, they will serve as McLanahan's executive team.

SUKUMAR BANDOPADHYAY (SME), professor of mining engineering at the University of Alaska Fairbanks, has been chosen to receive the 2014 Indian Institute of Technology BHU Distinguished Alumnus Award. He will receive his award at the 4th annual global alumni meeting Sept. 13, 2014 in Lisle, IL. ■



BANDOPADHYAY

Porto Alegre, Brazil was host to the 36th APCOM

by Sukumar Bandopadhyay, professor, University of Alaska, Fairbanks

The symposium series on the Application of Computers and Operations Research in the Mineral Industry (APCOM) was initiated at the University of Arizona in 1961. In 1973, at the 11th symposium at University of Arizona, a formal steering committee for the symposium, the Council for the Application of Computers and Operations Research in the Mineral Industry, was established. SME and the Australian Institute of Mining and Metallurgy were the first members. Since then, APCOM symposia have become truly international, where new ideas as well as original contributions have been presented. Since 1973, APCOM has become a major driver of innovation in the minerals industry, facilitating the advancement of computer and operational research methodologies. Thanks to the personal commitments of APCOM's loyal participants and supporters, the symposia continue to be a thriving success.

After the 35th APCOM in Wollongong, Australia in 2011, Brazil was selected as the next symposium venue. Preparations started immediately, with APCOM looking for good authors with good papers. This is the most challenging issue in organizing any successful conference — invite and select high-quality papers.



Those present at the APCOM scholarship presentation included (l-r) professor Joe Felipe Leite Coasta, symposium chair; Sukumar Bandopadhyay; Kadri Dagdelen and Camilla Zacche.

The 36th APCOM conference was held Oct. 4-8, 2013 at the Sheraton Hotel in Porto Alegre, Brazil, with 139 delegates in attendance. Four short courses were held prior to the conference. The program included the traditional areas of mineral exploration, mine planning and mineral processing, and included geostatistics, mine design, production planning, investment analysis, artificial intelligence, simulation, mineral automation, rock mechanics and data management systems.

The organizing committee received 112 abstracts, which resulted in 70 peer-reviewed papers — 58 of them were presented orally and 12 in poster sessions. International delegates represented more than 19 countries at the conference, exchanging experiences and knowledge. The participation of professors, researchers and students from universities around the world reinforces the importance and success of this forum which is held every two to three years.

The 36th APCOM was sponsored by the Federal University of Rio Grande do Sul, the Luiz Englert Foundation and by companies and institutions such as Maptek, Leapfrog, CNPq, CAPES (research agencies from Brazil) and Geovariances. The local organization also received support from Brazilian research agencies. Mining programs in Brazil have many students eager to join the mining industry, and approximately 40 undergraduate and graduate students participated at the symposium.

APCOM Brazil was a relaxed and stimulating conference with high-quality technical papers and discussions. The delegates had the chance to taste some of the Brazilian cuisine and culture during the social events organized during the congress.

Camilla Zacche da Silva received the 2013 APCOM scholarship at the conference. She majored in physics at the Federal University of Rio Grande do Sul and received an undergraduate degree in 2010. She joined the graduate program in mining engineering in 2011 and received her M.S. degree in geostatistics 2013. She is currently a Ph.D. candidate in the same program. Her master's dissertation approached factorization methods combined with kriging, which resulted in the paper she presented at the 36th APCOM, entitled *MAF Applied to Grade Estimation*.

APCOM 2015

The 37th APCOM will be held May 23-27, 2015 at the Westmark Fairbanks Hotel and Conference Center, in Fairbanks, AK. The focus of the 37th APCOM is to further the APCOM goal of contributing to effective decision-making processes throughout the entire minerals industry. Abstracts are due Aug. 1, 2014. Visit www.apcom2015.org for more information on the 2015 conference. ■

SME Foundation

(Continued from page 69)

36 years later, his statement still rings true to the need of an educated public regarding importance of mining in our society.

Shoemaker made his mark on the world through his research and discoveries. Now, he will leave a legacy to the SME Foundation. When considering what you have contributed to your profession, we hope that you, too, will consider leaving your legacy with a contribution to the SME Foundation. For more information, call AnnMarie Kochevar, SME Foundation Manager, at kochevar@smenet.org or 303-948-4239. ■

Stantec grants two McIntosh Engineering Scholarships

Stantec presented the McIntosh Engineering Scholarship to two University of Arizona (UA) students, Sean Hovorka and Levi M. Willard. The scholarship is an annual allocation of up to $10,000 a year and is designed to recognize exceptional students with a passion for mining. The scholarship was divided this year between two recipients and will be awarded during the course of their studies. Hovorka and Willard were recently joined by Sandy Watson, Stantec US & International Mining vice president, for the formal presentation of the award.

"As a part of the global mining community, we see our industry's shortage of skilled leaders in the years to come. That makes inspiring and supporting the next generation of the industry all that more important," said Watson. Young students like Sean and Levi represent the promising passion that will ultimately forge the future of our industry."

Through the generosity of Scott McIntosh, the scholarship extends up to four years and is dependent upon each student meeting pertinent, annual academic milestones. In addition to this year's recipients, Stantec continues to support past scholarship winners. ■



Sandy Watson (r) presents Levi M. Willard (l) with the McIntosh Scholarship at the University of Arizona.

RMCMI will hold annual meeting in Keystone

The Rocky Mountain Coal Mining Institute (RMCMI) will hold its 110th convention and annual meeting at the Keystone Resort and Conference Center, Keystone, CO, June 29-July 1, 2014. The conference theme is "The Western Coal Miner: Not an Endangered Species."

Matt Mead, governor of Wyoming, has been invited to be the keynote speaker. Other speakers include Gwenne Henricks, chief technical officer and vice president, Caterpillar; Alex Epstein, president of the Center for Industrial Progress; David Moss, vice president of the Kentucky Coal Association and Samuel Frimpong, professor at the Missouri University of Science anc Technology.

Highlights of the conference include two short courses, a four-day mine rescue evaluation, family events and a golf tournament. The 27th annual scholarship awards luncheon will be held on Monday. The closing luncheon and annual meeting will be held on Tuesday.

For information and registration, visit www.rmcmi.org. ■

CSM hosts shotcrete short course

Shotcrete, a comprehensive three-day short course, will be held Sept. 3-5, 2014 at the Colorado School of Mines (CSM) in Golden, CO. The course director is Raymond Henn, adjunct professor at CSM. Attendees will explore effective and sustainable uses of shotcrete. Economical and expedient, shotcrete is increasingly used for the support of excavation, geotechnical retaining walls, soil nails, underground construction and tunneling, mining, new structural walls and wall repair.

Under the instruction of industry experts, students will gain the knowledge needed to specify, design, and provide quality assurance of reinforced concrete construction using shotcrete complemented with American Concrete Institute specifications, guide and underground guide specification and Nozzleman certification documents. This course also provides an excellent opportunity for meeting and networking with shotcrete industry professionals.

This course is intended for owners, engineers, contractors, consultants and equipment suppliers involved in the design and implementation of above-ground structures, support of excavation, tunneling, mining, shaft construction and heavy civil and architectural projects.

Attendees will receive two continuing education units upon completion of the course. Registration is now open online. Enrollment is limited and applications will be accepted in the order received. The course fee is $1,585 through July 29, 2014 and $1,685 thereafter. Opportunities to become course sponsors at various levels are available online as well.

For more information, registration forms and a detailed course outline, visit www.csmspace.com/events/shotcrete. ■

Midwestern Industries introduces the MR-7 screener

The new Model MR-7 Screener from Midwestern Industries, with its compact, efficient design, is especially engineered for conveyor-type installations. The versatility of the screener allows it to be either cable-suspended of the front of a conveyor or pedestal-mounted. This deck combination, with end-tensioned panels, provides a screening unit that can effectively handle sand, gravel, crushed stone, coal, slag, topsoil, mulch, ash, recycled asphalt or concrete. The MR-7 screener is 122 x 213 cm (48 x 84 in.) and comes complete with a 1.5 kW- (2-hp), 230/460-V, 3-phase, 60-cycle, 1,750-rpm motor, V-drive components, a belt guard and conveyor installation carriage members.

The design of the screener allows the user to move the screener/conveyor combination to multiple job sites. One unique aspect of the MR-7 is the end-tensioned screen panels that enable conveyed materials to move along the full-screen surface until discharge. The entire width of the screener is used to full capacity, and the screen panels are easily changed for screening without costly downtime.



The MR-7 can be outfitted with a variety of screens depending upon the application.

The MR-7 is ideal for material screening in harsh conditions, because the unit can be made from stainless steel or carbon steel with corrosion-resistant coatings.

www.midwesternind.com/conveyor_screener_mr7.html

Double Coin offers new radial off-road tire

Double Coin tires has introduced the REM-19 45/65R45 L-5 radial loader tire for use on large loaders in mining and aggregate applications.

The REM-19 is engineered to provide excellent traction for heavy mining applications and to accommodate large loaders that require durability in a tire's bead and sidewall areas due to heavy lifting weights. It is also designed with a long-lasting, puncture-resistant tread face compound for optimal performance.

Designed with a wide footprint and center rib for stability, the tire features a nondirectional tread design for additional traction in multiple applications.

www.doublecointires.com

Fabric and steel buildings available from Legacy

Combining rigid-frame engineering with the proven benefits of tension fabric, Legacy Building Solutions offers the industry's first line of fabric buildings to incorporate structural-steel beams instead of open-web trusses. This engineering concept provides a high level of flexibility for storage of bulk material or equipment, vehicle maintenance shops, portable or stationary soil remediation facilities and other fabric structures used in mining operations.

Legacy buildings use a durable, rigid frame in place of the hollow-tube, open-web truss framing traditionally used for fabric buildings. Legacy's solid structural-steel beams are not vulnerable to unseen corrosion originating inside a tube. Additionally, the structural steel has multiple coating options, including hot-dip galvanizing, red-oxide primer and powder-coat paint.

The strength of the structural-steel frame provides several engineering advantages, including the ability to relocate buildings by towing or crane. The rigid frame also delivers the flexibility to customize buildings beyond the confines of standard shapes and sizes to the exact width, length and height required.

Legacy buildings feature high-quality, polyethylene fabric roofs that eliminate the corrosion concerns associated with metal-constructed facilities. A variety of PVC fabrics are also available. The durable fabric allows natural light to permeate the structure, while insulation can be added when required.

www.legacybuildingsolutions.com



Legacy steel components and fabric covers are backed by a 15-year warranty.

Abus celebrates 90 years of quality security solutions

In 1924, Abus was started by August Bremicker and his sons in the cellar of their family home in the small village of Wetter, Germany. The Bremickers entered the security industry producing padlocks, hasps and staples. During the past 90 years, the company has expanded to specialize in many different areas of security, now offering home, mobile and business solutions. Original concepts, such as the Diskus padlock, made Abus a premium brand that outlasts and outperforms its competitors.

The Abus disc lock is a special form of padlock with a disc shape that effectively resists the most common ways of forcing it open. The Diskus is made mainly of stainless steel and can be used where security and protection against corrosion are required. The Diskus family is available in models with diameters between 50 and 80 mm (2 and 3 in.). As a special order, the locks can be retrofitted with a disc cylinder, the Abus-Plus locking system.

Abus Granit padlocks meet the highest security standards and are considered to be among the most secure padlocks in the world. Their tensile resistance is more than 6 t (6.6 st). Innovative, luminous keys and the black Granit coating for optimal corrosion protection are characteristics of the product series. The Abus-Plus disc cylinder is one of the special features of the Granit range. This high-security locking system provides great resistance to manipulation attempts such as lock-picking.

www.abus.com

Aveva releases mobile app for plant design review

Aveva E3D Insight is now available for project decision makers in the power, process plant and mining industries. The Windows 8.1 app enables mobile users to comment and approve Aveva Everything 3D (Aveva E3D) designs from a tablet device.

Developed in collaboration with Microsoft, Aveva E3D Insight offers the ability to inspect, comment upon and approve designs at any time, from anywhere around the world. The user can quickly see the Aveva E3D model and its associated information and can inspect, manipulate and measure the model to check for potentially critical issues, such as object clashes, accessibility and noncompliance with design standards. The user can communicate directly with the project's design team and leave a permanent record of feedback in the Aveva E3D database itself. Key decisions are recorded without users being forced to collate multiple comments.



Authorized users of the Aveva E3D can set model status to preconfigured approval levels.

http://futureofplantdesign.aveva.com

Grieve oven is used to dry gold ore samples

The Grieve heated belt conveyor oven No. 864 is currently being used to dry gold ore samples at a customer's facility. The oven imeasures 2 x 10.5 x .5 m (6.5 x 3 5 x 1.5 ft) with a 1,650,000-Btu modulating natural gas burner to heat the oven chamber. A 679-m^3/min. (24,500-cfm), 15-kW (20 hp) recirculating blower provides vertical downward airflow to the workload.

This Grieve oven features a 1.5-m- (5-ft-) long, open-belt loading zone, a 10.5-m (35-ft-) long insulated heat zone with recirculated airflow and a 30-cm- (1-ft-) long open-belt unloading zone. It also has insulated walls and an aluminized-steel interior and exterior.

A 1.8-m- (6-ft-) wide, 33-cm (13-in.) galvanized steel, flat-wire conveyor belt with 1.2 kW (0.25 hp) motor drive, variable from 0.42 to 4.2 mm/s (5 to 50 ft/hr), transports the workload. All the safety equipment required for gas-heated equipment is provided for the belt conveyor oven, including a 4.24-m^3/min (1,500-cfm), 1.5-kW(2-hp), powered forced exhauster.

Controls on No. 864 include a conveyor belt start/stop, a current proportioning temperature controller, manual reset excess temperature controller, a variable SCR drive to control conveyor belt speed, pilot lights to indicate when the blower and heat are energized, pushbutton electronic ignition, an on-off heat switch and main oven control pushbuttons. The NEMA 12 control panel is equipped with a lockable fused disconnect switch. ■

www.grievecorp.com



Side access doors are provided along the length of the workspace to inspect the load and service the No. 864 oven heating chamber.

Coming Events/Short Courses

Upcoming SME Events

North American Tunneling Conference
June 22-25, 2014
JW Marriott
Los Angeles, CA, USA

Critical Minerals Conference
Aug. 3-5, 2014
Westin Denver Downtown Hotel
Denver, CO, USA

Professional Engineers Exam Review Course
Sept. 13-17, 2014
Westin Denver Downtown Hotel
Denver, CO, 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.

June 2014

11-12 • AIMS 2014 — 6th International Symposium on High Performance Mining
Karman Auditorium, RWTH Aachen University, Aachen, Germany
Phone: 49-241-80-95673 • Fax: 49-241-80-92272
email: aims@bbk1.rwth-aachen.de
www.aims.rwth-aachen.de

16-20 • Short Course on Grouting Fundamentals and Current Practice
Colorado School of Mines, Golden, CO, USA
email: kieffer@tugraz.at
http://csmspace.com/events/groutings

29-July 1 • 110th Rocky Mountain Coal Mining Institute Convention and Annual Meeting
Keystone Resort and Convention Center, Keystone, CO, USA
Phone: 303-948-3300
email: mail@rmcmi.org
www.rmcmi.org

29-July 4 • Shechtman International Symposium
Fiesta Americana Condesa Resort, Cancun, Mexico
email: symposiums@flogen.org
www.flogen.org/shechtmansymposium

August 2014

11-12 • MMME 2014 — International Conference on Mining, Material and Metallurgical Engineering
Clarion Congress Hotel, Prague, Czech Republic
email: info@mmmeconference.con
http://mmmeconference.com

13-15 • OPM 2014 — Oil Power and Mining
Orange County Convention Center, Orlando, FL, USA
Phone: 407-289-3434
email: info@oilpowermining.com
www.oilpowermining.com

27-28 • 3rd LatAm Mine Water Conference
Lima, Peru
Phone: 97146091570 • Fax: 97146091589
email: sonika.mendjoge@fleminggulf.com
http:energy.fleminggulf.com/latam-mine-water-conference

September 2014

5-9 • International Conference on Geoscience Education
University of Hyderabad, Gachibowli, Hyderabad, India
Phone: 91-824-4263384 • Fax: 91-80-2287367
email: ineso555@gmail.com
http://geoscied2014.webs.com

21-24 • International Minerals Engineering Conference
San Luis Potosi Convention Center, San Luis Potosi, Mexico
email: imec2014@i-mec.org
www.i-mec.org

21-28 • 43rd Conference of the Underwater Mining Institute
University of Lisbon, Lisbon, Portugal
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27-30 • Society of Economic Geologists 2014 Conference
Keystone Conference Center, Keystone, CO, USA
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email: darline@qbsoffice.com
www.seg2014.org

28-Oct. 1 • Solution Mining Research Institute Fall Technical Conference
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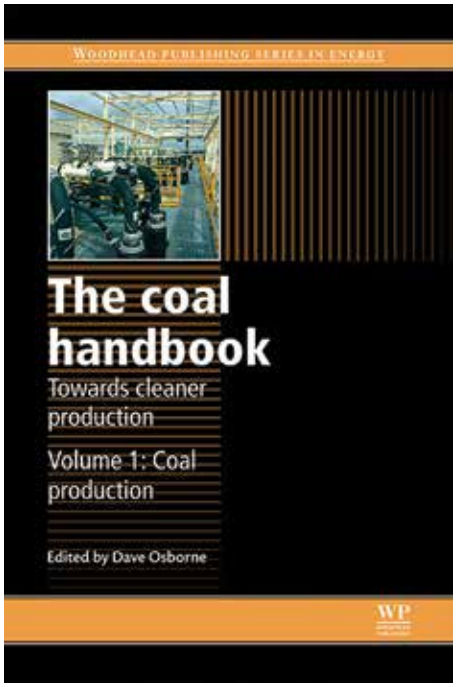
October 2014

7-8 • 7th West and Central Africa Mining Summit and Expo
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Phone: 65-6391-2535
email: jose@magenta-global.com.sg
www.magenta-global.com.sg/wacamining2014/index.php

28-29 • Offshore Energy Exhibition and Conference
Amsterdam RAI Exhibition and Convention Center, Amsterdam, The Netherlands
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www.offshore-energy.biz ■

The Coal Handbook Towards Cleaner Production

2013, edited by Dave Osborne, Woodhead Publishing Series in Energy, Woodhead Publishing Ltd., Cambridge, UK, an imprint of Elsevier, http://store.elsevier.com/Woodhead-Publishing-/IMP_209; Volume 1, 776 pp., ISBN 978-0-85709-422-3, $345, print or eBook; Volume 2, 576 pp. ISBN 978-1-78242-116-0, $295, print or eBook.



Coal remains an important fossil fuel resource for many nations due to the large amount of remaining resources, its relatively low production and processing cost, and the potential high-energy intensity. There are certain issues that surround its use, however, including emissions of pollutants and a growing concern about climate change.

The Coal Handbook: Towards Cleaner Production, volume one, reviews the coal production supply chain from analysis to extraction and distribution. Other key topics in volume one include an exploration of coal characterization, formation, petrography, reserves, sampling, and analysis and an examination of coal extraction and preparation and advances in coal mining technology, underground coal-gas extraction, coal sizing, comminution and cleaning, and solid-liquid separation technologies.

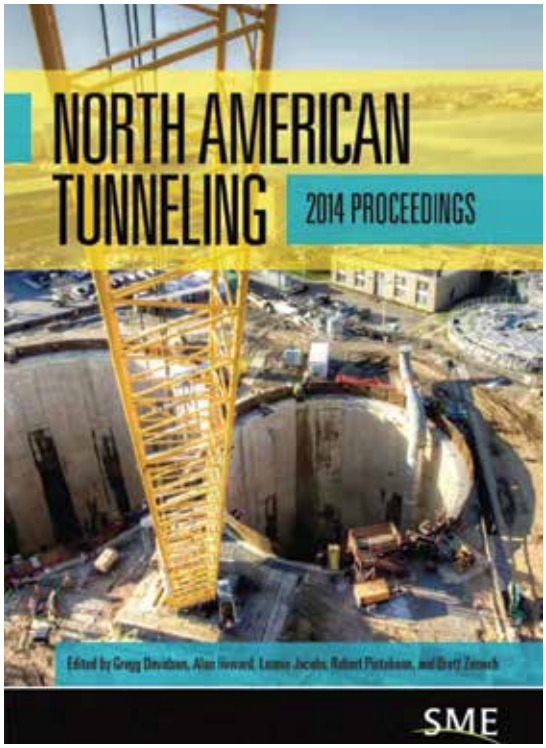
Volume two explores global coal use in industry. Key topics in volume two include a review of the social and economic value of coal, emissions from coal utilization and the handling, impact and utilization of coal waste. It also studies emerging and future issues surrounding industrial coal utilization and resources, production, and the use of coal in established markets and emerging markets, such as Brazil, the Russian Federation, India, Indonesia and China.

Andrew Vince, Elsa Consulting Group, Mackay, Australia, reviewed the book and commented, "The most knowledgeable and eloquently articulate professionals in today's world coal genre have been pulled together by Dr. Dave Osborne. Over a three-year period, Dave led the individual chapter authors to provide, what I consider to be, the best, most comprehensive and certainly the most contemporary treatise of the elements of coal.

With individual authors widely known and respected in their own right, their combination, collation and linkage into a single text presents a formidable treatise that represents an awesome body of work. The division of subject matter facilitates selective reading if desired and its sequencing is conducive to a very good read." ■

North American Tunneling 2014 Proceedings

2014, edited by Gregg Davidson, Alan Howard, Lonnie Jacobs, Robert Pintabona and Brett Zernich, published by SME, 12999 E. Adam Aircraft Cir., Englewood, CO 80112, USA, www.smenet.org/store, email books@smenet.org, phone 303-948-4225, hardcover, 1,216 pp. plus CD, ISBN 978-0-87335-400-4, $149 member, $139 student member, $199 list. Also available as an eBook.



The North American Tunneling Conference is the premier forum in which to discuss new trends and developments in underground construction in North America. The *North American Tunneling: 2014 Proceedings* reflects the theme for the 2014 conference, Mission Possible. The authors share new theories, novel innovations and the latest tools that make possible what once was perceived as impossible.

The authors of the 128 papers offer the latest case histories, expertise, lessons learned and real-world applications from around the world. They cover the successes and failures of challenging construction projects, design issues, performance, future projects and industry trends, as well as ground movement and support, structure analysis, risk and cost management, rock tunnels, caverns and shafts, TBM technology and the selection of water and waste water conveyance. Contents are divided into sections on technology, design, planning and case studies. ■

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FALL 2014 SHORT COURSES

• September 26-27	Introduction to Engineering Contract Law
• October 10-11	Modern Corporate Organizations in the Mineral Industry
• October 17-18	Introduction to Social and Environmental Assessment



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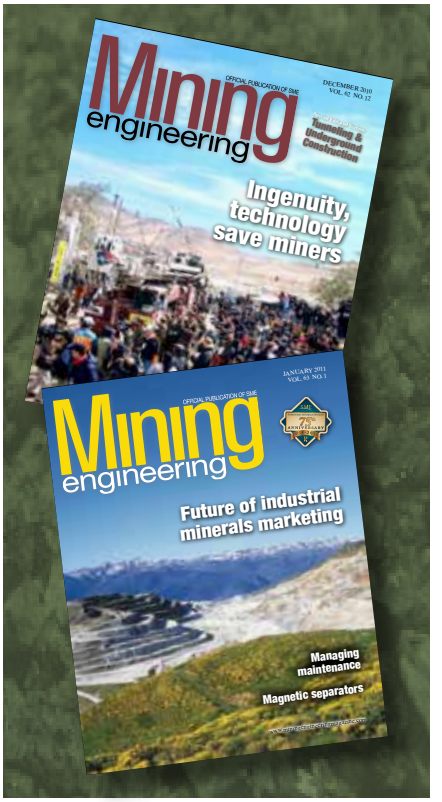
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Universities bail on coal



Steve Kral,
Editor

California may **divest coal holdings**

California Gov. Jerry Brown in May suggested to the board of regents at the University of California (UC) that the school consider divesting its endowment of any connection to the coal industry, according to a story in the *Los Angeles Times*. Brown is a believer in climate change and has blamed southern California's recent series of forest fires on global warming.

If UC's regents agree to the governor's proposal, it would join several other colleges, including Stanford University, in divesting themselves of investments in fossil fuel companies, specifically coal. UC's general endowment fund stands at about $7.7 billion.

Student activists at UC, who believe that climate change is primarily due to the burning of fossil fuels, are urging the board of regents to sell off holdings in large fossil fuel companies. Brown, who is member of the school's board of regents, did not go that far. Instead, he told the regents at a meeting that he would be willing to consider "to some targeted disinvestment," meaning coal, and not the entire fossil fuel industry. "There could be something there," he said.

There is a disturbing attitude among many students that doing away with fossil fuels will stop climate change and all will be right with the world. They do not understand that alternative fuels are currently not technologically capable of meeting current energy demands, much less future needs. And not just in the United States, either. It is a global issue. Universities need to shoulder much of the responsibility for this lack of understanding on the students' part.

The divestment is not a new subject with the UC regents. They have discussed the issue before but backed off because of concerns about what such a move would do the university's finances. Now, however, the board may be more receptive. A report is due in July that is to provide options and potential impacts of such divestments, and then maybe the regents will develop a new policy in the fall.

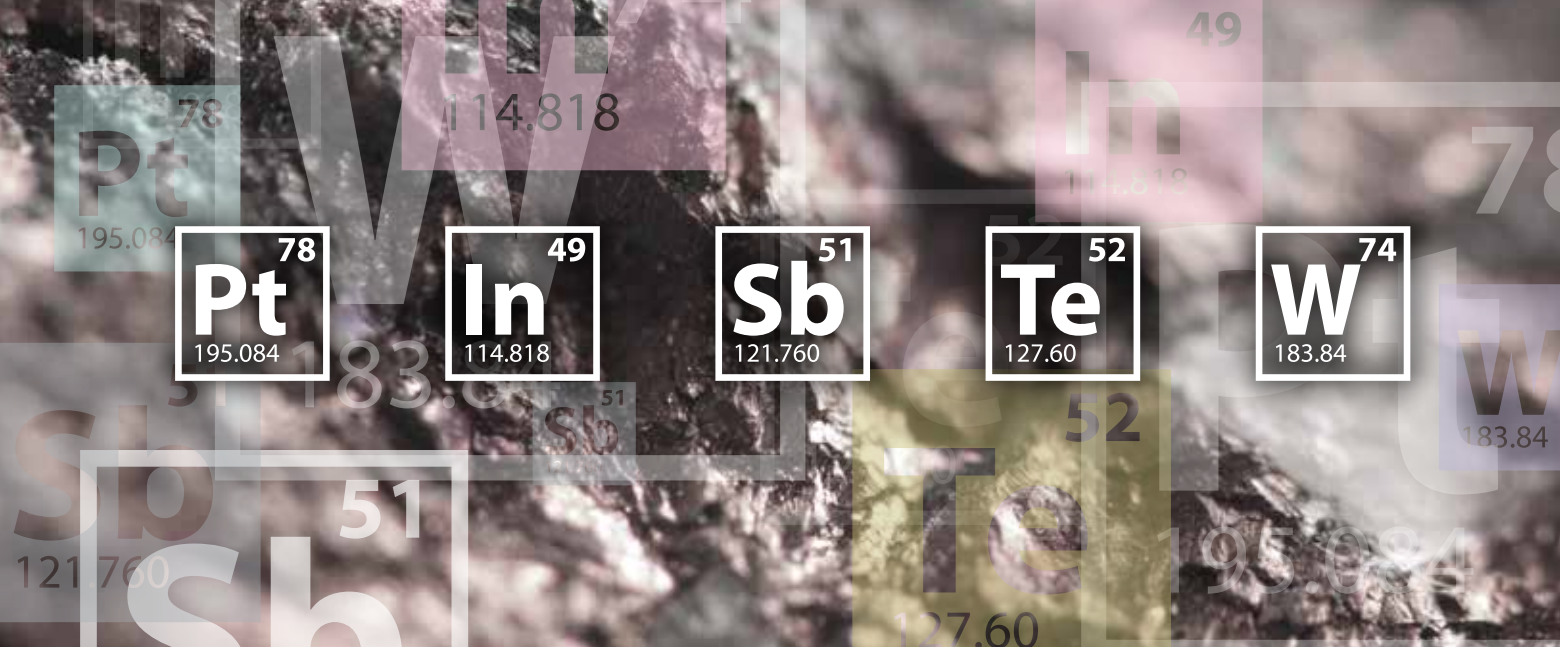
Waiting for a report is not a bad idea. The university reported that about $39 million of its central endowment funds is currently invested in 67 of the 200 largest fossil fuel companies. And it has additional holdings in bonds, mutual funds and commodity contracts. While $39 million is not a large part of the university's $7.7 billion in endowment funds, it's still a fair amount of money. The regents need to also consider the amount of research funding it could lose.

Meanwhile, Stanford's Board of Trustees earlier in May approved a resolution to not directly invest in in companies for which coal extraction is their primary business. The school will also divest any holdings it already has. Like UC, the decision was partly based on pressure from students.

As of August 2013, Stanford's endowment fund was valued at $18.7 billion. The school does not disclose its holdings or their value, the *Los Angeles Times* said. However, a university spokesperson said its current investments in fossil fuel companies was not large enough to have "a significant impact" on the portfolio.

In explaining the trustees' decision, university president John Hennessy said, "Stanford has the responsibility as a global citizen to promote sustainability for our planet, and we work intensively to do so through our research, our educational programs and our campus operations. Moving away from coal in the investment context is a small, but constructive, step, at Stanford and elsewhere, to develop broadly viable sustainable energy solutions for the future."

Stanford and UC join Pitzer College in San Francisco and two other community college districts in northern California that are, likewise, divesting their holdings in fossil fuel companies. There are about a dozen other schools throughout the United States that are doing the same thing. ■



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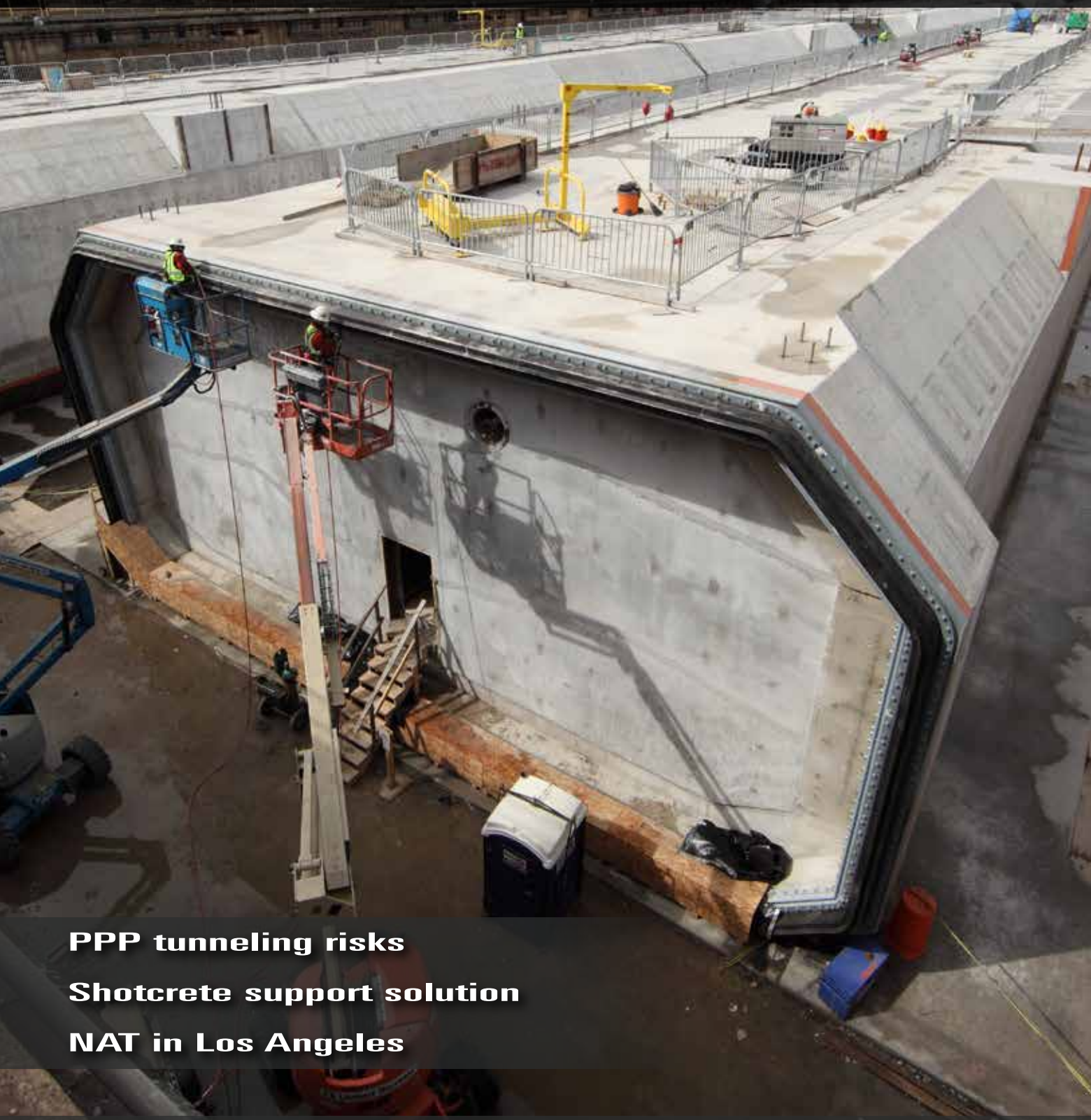
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New Orleans is also known as the birthplace of jazz. Early jazz greats like Louis Armstrong, Buddy Bolden, Jelly Roll Morton and King Oliver got their start in the nightclubs of Storyville, a red-light district that flourished from 1897 to 1917. The city's musical tradition remains strong as New Orleanians like Harry Connick Jr., the Neville Brothers, and Wynton and Branford Marsalis, and events like the New Orleans Jazz and Heritage Festival and French Quarter Festival, share these gifts with the rest of the world.

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COVER STORY



In this issue — Public-private partnerships pose significant risk for all private sector participants. Nasri Munfah and David Hatem explain, page 19. An improved shotcrete support system was designed for Seattle's University Line Extension, page 10. Cover photo is of the Elizabeth Tunnels Project, a PPP project. Photo courtesy of Virginia Tunnels Project.

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CHAIRMAN'S COLUMN

Lots of activity in the UCA

The Underground Construction Association of SME (UCA) is busy. On the strategic planning front, to achieve our mission: "Promote the responsible development and use of underground space and facilities," the UCA Executive Committee has identified three strategic goals. The UCA will:

- 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 all key constituencies.
- Improve the effectiveness and efficiency of the underground construction industry.

You probably recently received a request for help in defining the action plan — specific tasks that can be accomplished in the short term — that will enable us to meet these strategic goals. I encourage you to volunteer to serve on the committee of your choice. We need all of the good ideas from our membership to help the UCA meet its mission. At our meeting during the North American Tunneling (NAT) conference in Los Angeles, CA in late June, the committee structure will be established and an announcement made. Stay tuned.

On the international front, this year's ITA World Tunnel Congress was held in Iguazu Falls, Brazil. For those who have not been to the Falls, it is even more impressive than Niagara. The Brazilian rain forest is a beautiful site. More than 50 U.S. members attended the WTC this year to participate in working groups, listen to technical papers, visit the exhibition hall and enjoy Brazilian hospitality. The working groups are an excellent method of technology transfer among underground industry from different cultures. See http://uca.smenet.org/ITA for a listing of the U.S. representatives on the ITA working groups and the material available to UCA members. Another objective of our delegation was to encourage members of the international tunneling community to come to San Francisco, CA in April 2016, when the World Tunnel Congress will be held at the Moscone Convention Center, in conjunction with the NAT 2016 conference.

Domestically, the UCA is planning several conferences during the next year to facilitate technology transfer and training within the United States. In addition to the 2014 NAT conference in Los Angeles, another Cutting Edge conference will be held in New York City Nov. 2-4, 2014. As always, the George A. Fox conference will be held in January 2015, also in New York City. I urge you to plan to participate in these conferences.

Lastly, through the good work of Chris Laughton's committee, the UCA is nearing the release of a presentation entitled "Benefits of Underground Construction." This presentation will be geared toward selling underground instead of above-ground solutions to infrastructure problems, and focused on identifying the advantages of going underground. It will be available on the UCA website for member use in the near future.

UCA membership continues to grow in size, recognizing the benefits that accrue to members. Clearly, there are a lot of things going on. ■

William W. Edgerton,
UCA of SME Chairman

SR 99 engineers consider plans to free Bertha

One of the greatest challenges facing engineers working to free the tunnel boring machine (TBM) trapped underground in Seattle, WA could be ground water.

The TBM, Bertha, which is the largest in the world, became stuck on Dec. 6, 2013. Attempts to restart the Hitachi Zosen-built machine failed when it was discovered that the main bearing seal was overheating. To repair the TBM, a pit will have to be dug.

The Washington State Department of Transportation (WSDOT) released a new schedule for the SR 99 tunnel project that calls for tunneling to resume in March 2015.

The first step of the plan is to dig a pit to access the machine. This plan calls for a watertight ring of buried shafts, allowing the dirt within to be scooped away, to form a circular work zone. Bertha would then grind its way into this concrete-walled pit from the south, before repairs begin midyear.

The fear is that the loss of ground water could damage buildings in nearby Pioneer Square.

The Seattle Times reported that most of the shafts will be 2 m (7 ft) in diameter, to resist tremendous soil and water pressures. Part of the ring will include, not only a row of new columns, but have a dual row, by incorporating some of the buried columns that were previously installed to protect the Alaskan Way Viaduct.

Concrete grout must be injected to fill any gaps, not only in the ring but several yards around.

The worries include that ground water might pour into the repair pit, hampering workers and equipment as they remove the giant cutterhead and fix or replace the damaged main bearing.

And if ground water suddenly rushes in, the water loss elsewhere could destabilize old buildings in Pioneer Square, or the viaduct itself, *The Seattle Times* reported.

Previously, Seattle Tunnel Partners (STP) installed a protective north-south line of buried pillars to shield the viaduct from Bertha's vibrations. Gaps of 12.7 cm (5 in.) were left between them, to let ground water migrate more or less normally. Now in a design change, STP's pit designer, Brierley Associates, is proposing to fill those gaps with grout. That way, water would not follow Bertha into the pit.

"Part of the plan includes sealing the pilings placed along the tunnel route to prevent water from getting inside the access pit when the machine breaks through the wall," Matt Preedy, deputy Highway 99 administrator for the Washington State Department of Transportation told *The Seattle Times*.

Ground water presents a significant challenge. Tests performed in 2002 and 2010 indicated that the water content is nearly 35 percent in the soil where Bertha is stranded, at South Main Street. This generates a pressure nearly three times that of the atmosphere.

The repair ring in Seattle will be 25 m (83 ft) in diameter and 36 m (120 ft) deep, according to diagrams Preedy showed the Seattle City Council.

"The designers are currently predicting, not only what sort of effects the viaduct might see from that shaft, but also any buildings in Pioneer Square," he said. ■

New SR 99 schedule released

The Washington State Department of Transportation (WSDOT) released a new schedule for the SR 99 tunnel project that calls for tunneling to resume in March 2015.

Construction was scheduled to begin in May on the pit that Seattle Tunnel Partners (STP) will use to access and repair damage to the tunnel boring machine (TBM), which stopped tunneling in December. Building the pit is the first of several steps STP has laid out to resume tunneling:

- Late May: Begin building the access pit's underground walls.
- Late July through September: Excavate the pit.
- October: Remove the machine's cutterhead and begin repairing damage to the seal system and main bearing.
- February 2015: Test machine to ensure it is ready to tunnel beneath downtown.
- Late March 2015: Resume tunneling.

WSDOT said STP hopes to recover as much as four months of schedule to meet the November 2016 tunnel opening date that was established in the 2010 request for proposals.

STP plans to have crews replace the machine's main bearing and install a more robust seal system, which could include strengthening the seals, installing redundant systems and adding monitoring equipment. Additional details will be included in a plan to be submitted to for review by June 16, WSDOT said in a statement.

The repair schedule will include additional time to accommodate potential improvements to the machine that STP or the machine's manufacturer, Hitachi Zosen Corp., might choose to make after the cutterhead is removed and crews are able to perform a full inspection. ■

Crossrails project reaches 75 percent completion milestone

With the breakthrough at London's Whitechapel station on April 4, the Crossrail project reached the 75-percent completion milestone.

More than 32 km (19 miles) have been bored as part of the £14.8 billion project, Europe's largest railway and infrastructure construction project.

The 150-m- (500-ft-) long tunnel boring machine, named Victoria, began boring at Limmo Peninsula in east London at the end of 2012. On April 4, Victoria broke into the huge underground space at Whitechapel, where work is taking place 35 m (114 ft) below the surface, to create more than a kilometer of new platforms and passenger tunnels for the new Crossrail station.

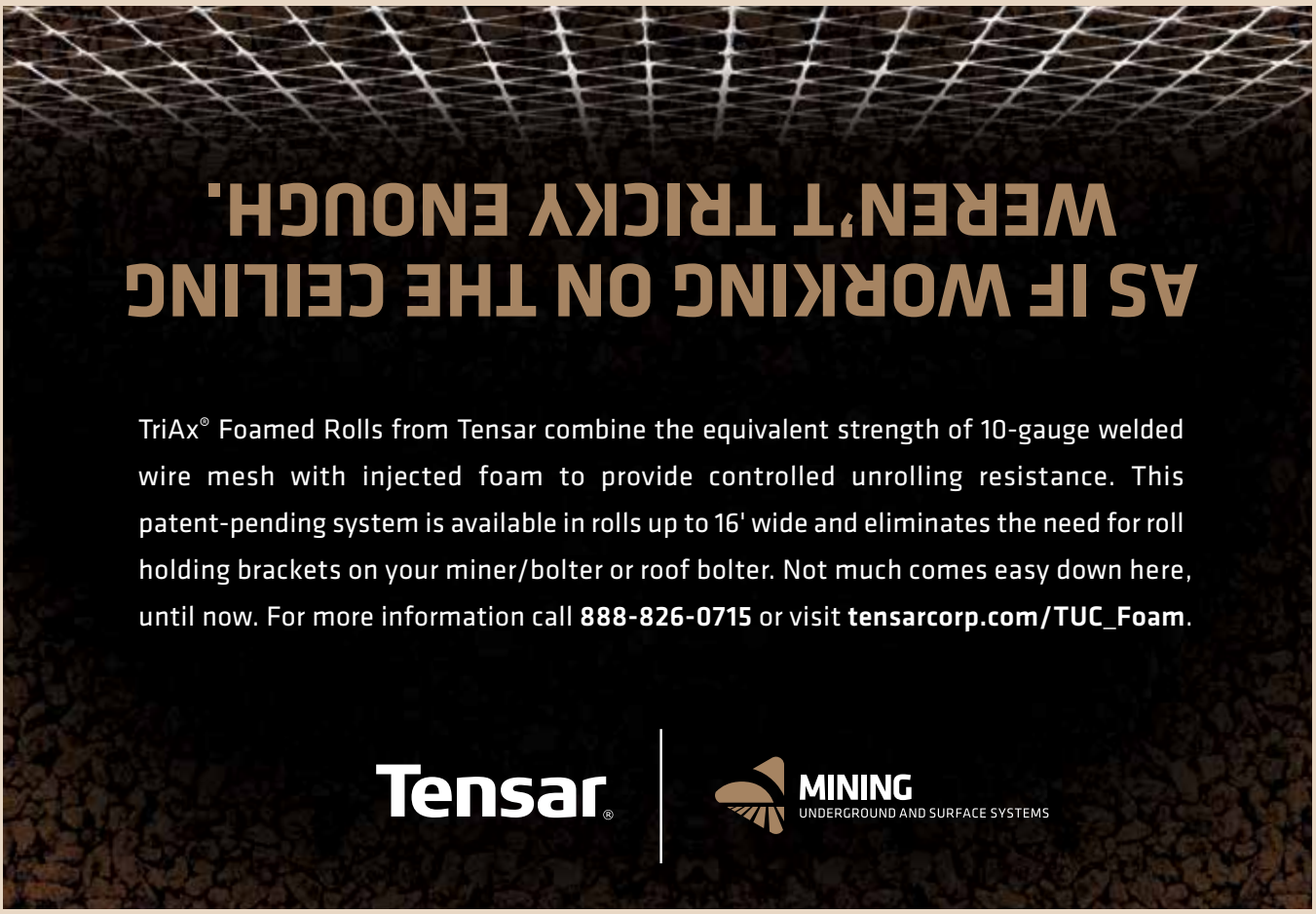
Tunneling will continue in the second half of 2014 and the project's focus will begin to shift to the job of fitting out the stations and tunnels. During tunneling operations, more than 2.5 Mt (3 million st) of earth have been removed by eight boring machines, of which three have already finished their tasks.

"We're tantalizingly close to finishing what is without doubt a monumental feat of engineering," said London Mayor Boris Johnson.

"It's quite remarkable what the Crossrail team has achieved so far, and we now look forward to the next exciting stage of the project - the fitting-out of the Crossrail stations of the future."

When Crossrail opens in 2018, it will increase London's rail-based transport network capacity by 10 percent and cut journey times across the city, bringing an extra 1.5 million people to within 45 minutes of central London.

Running from Reading in Berkshire in the west to as far east as Shenfield in Essex, Crossrail will pass through 40 stations and reduce cross-London journey times. ■



$403 million to be directed to East River tunnel repairs from superstorm Sandy damage

The U.S. Federal Emergency Management Agency (FEMA) will award New York's Metro Transportation Authority (MTA) $403 million for its efforts to repair and strengthen two key East River tunnels that were flooded during superstorm Sandy, *Newsday* reported.

The MTA will receive $329 million for fixes to its Hugh Carey/Brooklyn Battery and Queens-Midtown tunnels and another $74.5 million for flood-control projects.

In March, *T&UC* reported that the MTA was awarded $866 million to repair the Montague, Steinway and Greenpoint tunnels (March 2014, pp. 7). Some of that funding was also set aside to fund projects to protect against future flooding.

The funding for the East River tunnels will include the construction of new flood walls at tunnel plazas and other facilities, elevation of mechanical equipment, installation of submersible pumps and flood-proofing of some areas inside the tunnels.

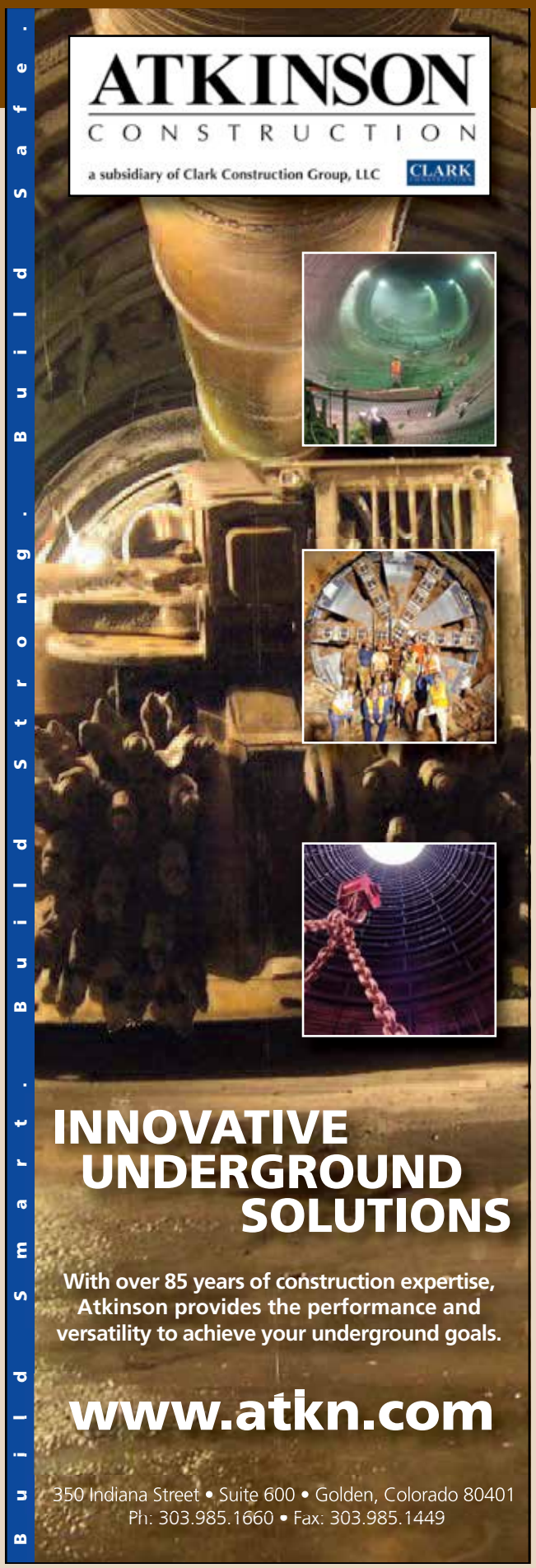
"As a result of this investment, we will be able to rebuild and modernize two of the most vital arteries — not only in New York, but in all of America — better and stronger than they were before Sandy," said Sen. Charles Schumer (D-NY), a sponsor of the Sandy Recovery Improvement Act, under which the funding was authorized.

"When we drafted the Sandy legislation, it was this type of damage and this comprehensive type of reimbursement that we had in mind," he said.

The MTA and FEMA settled on the amount of funding as part of a new pilot program, under which municipalities agree on a cap for reimbursable costs in exchange for expediting payments, federal officials said.

The grant will allow the MTA to "permanently repair" the two passageways and "add additional safety measures," FEMA said in a statement.

FEMA had previously provided the MTA $3 million in Sandy funding, and the Federal Transit Administration provided another $1.2 billion, federal officials said. ■



Judge rules in favor of Westside subway plans

Los Angeles County Superior Court Judge John A. Torribio ruled that transit officials followed environmental laws when choosing a route that will require tunneling under Beverly Hills High School for the long-awaited Westside Subway extension, *The Los Angeles Times* reported on April 2.

It was one of the final hurdles for the project.

In a 15-page decision, Torribio wrote that the Los Angeles County Metropolitan Transportation Authority's (Metro) five-year, $13.8-million environmental review process was thorough and fair.

The Beverly Hills School District and the city of Beverly Hills, which sued Metro two years ago claiming in part that risks of tunneling under the school were not adequately considered, can appeal the decision.

Transportation officials said the ruling effectively ends a generation of controversy and studies over the subway extension, which will connect downtown to West Los Angeles and serve one of the nation's most chronically congested commuter corridors. As currently planned, the 14-km (9-mile), $5.6-billion line, slated to open in 2035, will include seven new stations between Koreatown and Westwood.

Metro staff said in a prepared statement that the agency is looking forward to "working with all the communities along the alignment, including Beverly Hills."

"It validates Metro's decision to bring the subway to West Los Angeles safely, while serving the greatest number of riders."

L.A. County Supervisor and Metro board member Zev Yaroslavsky

Had Metro lost the lawsuit, the Westside subway extension could have faced years of delay and millions of dollars in extra costs while new environmental impact studies were completed, Metro spokesman Dave Sotero said.

The route Metro has chosen includes a station near Constellation Boulevard in Century City, two blocks west of Beverly Hills High School. It will require tunneling under parts of the campus. Metro considered an alternative route along Santa Monica Boulevard but discarded it after agency studies found a complex earthquake fault zone in that area.

"The Constellation Station is located in the middle of high rise office buildings that house thousands of potential subway riders," Torribio wrote. The Santa Monica Boulevard station favored by Beverly Hills "would require these same riders to walk a considerable distance to access the subway."

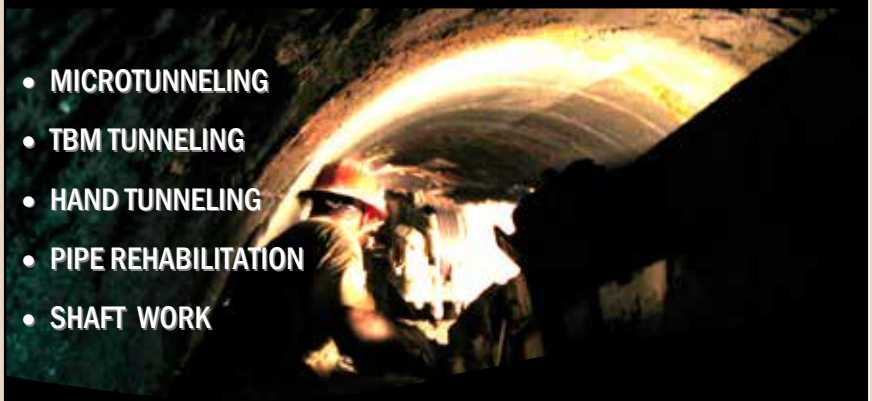
Los Angeles County Supervisor and Metro board member Zev Yaroslavsky, whose district includes the Westside, said in a statement that he was "gratified" by the ruling. "It validates Metro's decision to bring the subway to West Los Angeles safely, while serving the greatest number of riders," he said.

Last year, the city of Beverly Hills sued the Federal Transit Administration and the U.S. Department of Transportation over federal grants and loans allocated to the subway, saying the project violated environmental, transit and administrative laws. ■

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Robbins TBMs break through in Malaysia

Malaysia's capital Kuala Lumpur is a humid tropical metropolis with millions of inhabitants, and fresh water is in demand. A new tunnel was commissioned by the Malaysian Ministry of Energy, Green Technology and Water (KeTTHA), drawing water from the rainforest river Semantan and into the capital to address projected shortages for domestic and industrial use.

In 2014, three 5.23-m (17.16-ft) Robbins main beam tunnel boring machines (TBM) successfully completed excavation of the Pahang Selangor Raw Water Tunnel, also the longest tunnel in Southeast Asia. The massive 44.6-km (27.7-mile) long tunnel passes through the Titiwangsa mountain range under cover as high as 1,246 m (4,087 ft) and below geothermal features including hot springs.



The Robbins main beam TBMs excavated high cover hard rock conditions with durable back-loading cutterheads — the smallest ever designed to be mounted with 48 cm (19-in.) disc cutters.

Given the highly variable conditions, including hard granite up to 200 MPa UCS, multiple fault zones and quartz dykes, three separate TBM drives were proposed. Sections of NATM near the inlet and outlet portals were also used in sedimentary rock and granite. KeTTHA selected Shimizu Corp. and Nishimatsu Construction of Japan, along with local companies IJM Corp. and UEM Builders Bhd. (SNUI JV), as the contractor. The decision to use Robbins TBMs for the majority of tunneling was a clear one for the JV: "The open-type main beam TBM is number one in the world. I have used other machines, but this design is simpler and easier to use, and more powerful," said Nakano, deputy project manager for the SNUI JV.

All TBMs recently completed tunneling for this extensive project. The first TBM excavated 11.2 km (7 miles) and broke through in March 2013. The other two machines excavated 11.3 km (7 miles) and 12 km (7.5 miles) and met in the tunnel in mid-February 2014. "This is something we all look forward to in the tunneling industry," said Robbins field service manager, Andy Birch. "We get through all of

(Continued on page 9)

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Jacobs Associates opens office in Sydney, Australia

Jacobs and Associates' Sydney office currently supports ongoing projects in the city, including the North West Rail Link. These are the latest in a long list of Jacobs Associates' Australian projects. The firm's history in the region dates back to the 1950s, when its founder J. Donovan Jacobs was involved with the Snowy Mountains hydroelectric scheme. Since that time, the firm has served on more than 40 major tunneling projects and tenders in the region.

Mark Trim, a lead associate with Jacobs Associates, has played a key role in establishing the office. Trim has 15 years of experience as a design engineer specializing in permanent and temporary underground structures, with an emphasis on tunnel design, deep excavation support systems, soil-structure interaction and ground improvement technology. ■

Brierley earns distinguished alumnus award

On March 12, 2014, Tracy Lundin, President of the Civil and Environmental Engineering Alumni Association, presented Gary Brierley the Distinguished Alumnus Award from his alma mater, the University of Illinois at Urbana-Champaign.

Brierley was recognized for his outstanding career working on the design and construction of underground projects, for extensive contributions in the engineering profession as a member of many technical and professional societies, and for teaching and mentoring young engineers on the topics of tunnel design and construction, subsurface investigations, rock mechanics and professional practice.

The evening of the award ceremony, Brierley was accompanied by his friends and colleagues from the underground construction industry. ■

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Twin Box Tunnels – Liberty University, Lynchburg, VA

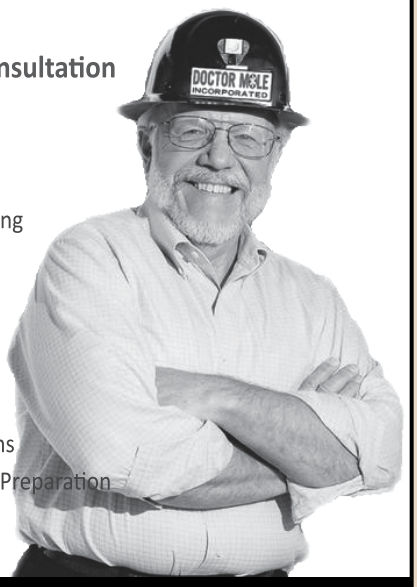
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gbrierley@drmoleinc.com or 303.797.1728

Robbins: Three TBMs were used on project

(Continued from page 7)

the hard work and eventually we break through. It's a great feeling, and I'm very happy for this joint venture and for Robbins."

The machines maintained excellent advance rates throughout the project despite many challenges including fault zones, variable rock conditions, high rock temperatures and frequent electrical storms that required machine stoppage. Due to the hot springs, water ingress at temperatures up to 56° C (133° F) was recorded. Maximum rates of 49 m (161 ft) in one day, 198 m (650 ft) in one week and 657 m (2,156 ft) in one month were nonetheless achieved — good rates that were at least partially attributed to the early installation of fiber mortar shotcrete as primary ground support. The near-zero rebound system, with its quick set time of 30 minutes, saved a significant amount of time compared to conventional ground support methods. Developed by Japan-based Denka and MCM, the project is the first time the material has been used outside of Japan and was able to successfully stabilize tunnel walls even in loose and collapsing ground.

High-tech design was also a factor in project accomplishment. To tackle the high cover and tough geology, all machines were equipped with custom back-loading cutterheads and durable large diameter cutters – the smallest diameter cutterheads to ever be outfitted with 48 cm (19-in.) cutters. The machines also had streamlined operator's cabs with touch screens and wireless operation, able to stream data to site offices and to a project website for worldwide analysis. Behind each machine, Robbins continuous conveyor systems moved muck efficiently from the machine face.

Along with custom design and innovative ground support, the assistance provided by Robbins was integral to the project's success. "The field service team was good and supported us on our project," said Ohashi, mechanical engineer for SNUI JV at the breakthrough of the first TBM, "I am pretty happy [with the result]." ■

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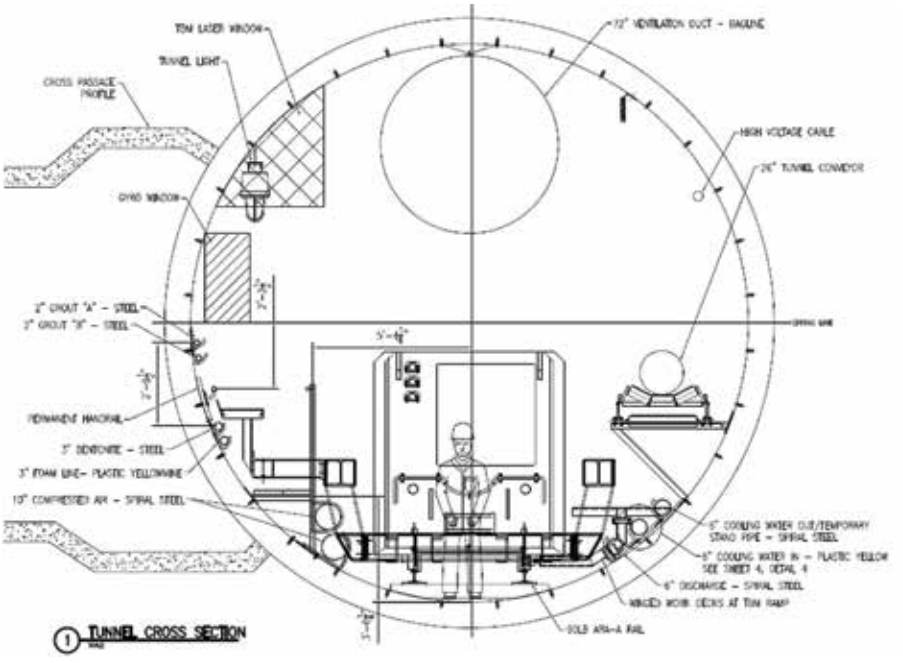
Opening supports to segmental linings: A novel shotcrete support solution

In a world of technology and electronic communication, it is easy to forget what engineers do best with a problem: sitting around a table, exchanging views and ideas with sketches and respecting everyone's view. This was the approach adopted in the project to arrive at a solution for the cross passage opening support for the Seattle University Link Extension.

Schedule and space constraints usually impede concurrent cross passage excavation and tunnel boring machine (TBM) operation. And where the space is constrained, opening support solutions that maximize available cross sections are of great benefit. While there are a number of solutions that minimize space, some of these solutions can require expensive steelwork and extensive drilling and fixing. However, following a detailed round-the-table discussion of the options and constraints, it was identified that a shotcrete shell would not only limit obstruction of the space during installation, but also permit easy installation, particularly around services, and avoid costly steelwork and drilling and fixing.

FIG. 1

Typical tunnel cross section.



Background

University Link Extension is a 5.07-km (3.15-mile) extension of the existing Central Puget Sound Regional Transit Authority (Sound Transit) light rail system that runs in twin-bored tunnels from downtown Seattle, WA north to the University of Washington, with stations at Capitol Hill and on the University of Washington campus near Husky Stadium. University Link will serve the three largest urban centers in the state of Washington — downtown Seattle, Capitol Hill and the University District. By 2030, the University Link line alone is projected to add 70,000 boardings a day to the light rail system.

Contract U220 comprises site preparation, slurry wall construction and partial excavation of the University of Washington Station box and excavating the 3.48 km (2.16 miles) of twin-bored 6.55 m (21.6 ft) excavated diameter tunnels from the University of Washington Station to Capitol Hill Station as well as construction of multiple cross passages between the twin-bored tunnels, permanent invert and walkway concrete, wet standpipe and permanent electrical installation in the running tunnels. The running tunnel sections were excavated with earth pressure balance TBMs and had the final lining constructed during excavation using bolted and gasketed precast concrete segments.

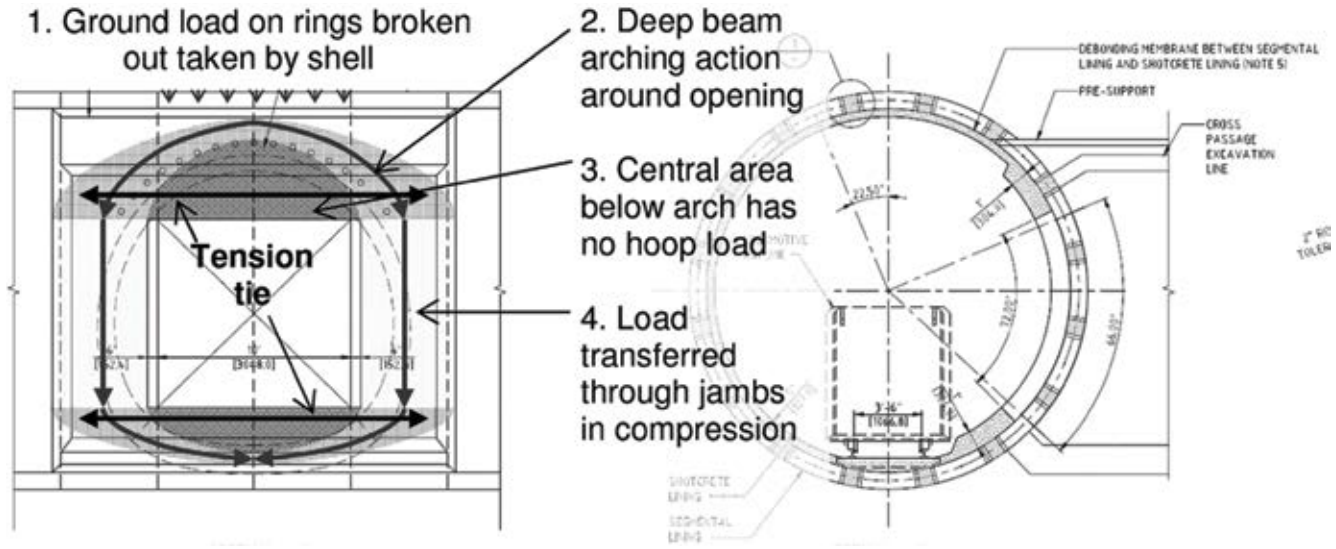
On March 25, 2009 a joint venture of Traylor Bros. Inc., and Frontier-Kemper Constructors (TFK JV), both of which are headquartered in Evansville, IN, submitted the lower of two bids received at $309,175,274. This was

Anthony Harding, Malcolm Chappell, Matt Burdick and Michael Krulc

Anthony Harding and **Malcolm Chappell**, are principal tunnel engineer and chief engineer, CH2M Hill and **Michael Krulc**, member UCA of SME, and **Matt Burdick**, are project manager and project manager, Traylor Bros. Inc., email mkrulc@traylor.com.

FIG. 2

Shotcrete support option with indicative structural behavior.



significantly lower than the $354 million bid price offered by the second bidder and the published Engineer's Estimate ($395 million).

Construction management was provided to Sound Transit by a joint venture of CH2M Hill and Jacobs Engineers. Engineering design was provided by a joint venture of Jacobs Associates, HNTB and Earth Tech, including crosspassage design, initial lining design and a potential method for providing temporary support to the TBM tunnel segmental lining around openings cut for access into the cross passages. The offered support option relied upon a series of rolled steel beams and braces (commonly referred to as hamster cages) that are erected inside the tunnel and rigidly blocked against the intrados of the segmental lining. TFK hired Halcrow Inc, which also designed the segmental lining for TFK, to provide design services for the temporary propping system.

Schedule

The contract allotted a total of 41 months from notice to proceed to substantial completion for the U220 project, allowing 15 months for site preparation, station box slurry wall construction, station box excavation and invert concrete construction, and a further 13 months for TBM mining and all cross passage and tunnel finishing work. With 16 cross passages to complete, this would not be possible unless cross passage work started before completion of TBM mining. Thus, TFK decided that cross passage excavation and TBM mining would have to occur simultaneously in the same tunnel to achieve the required substantial completion deadline. Additionally, two cross passages

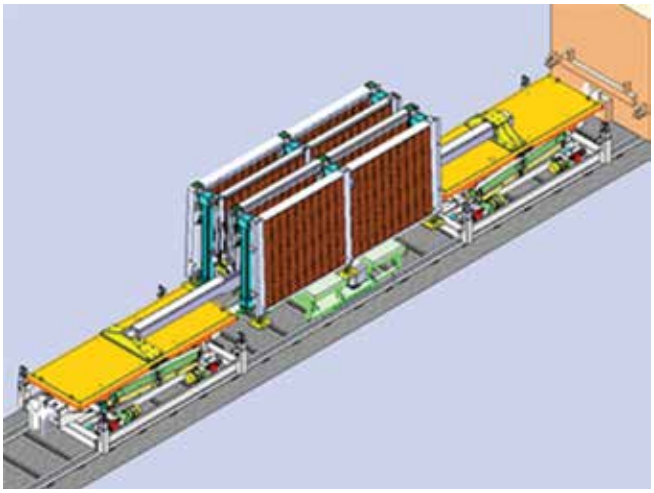
TABLE 1

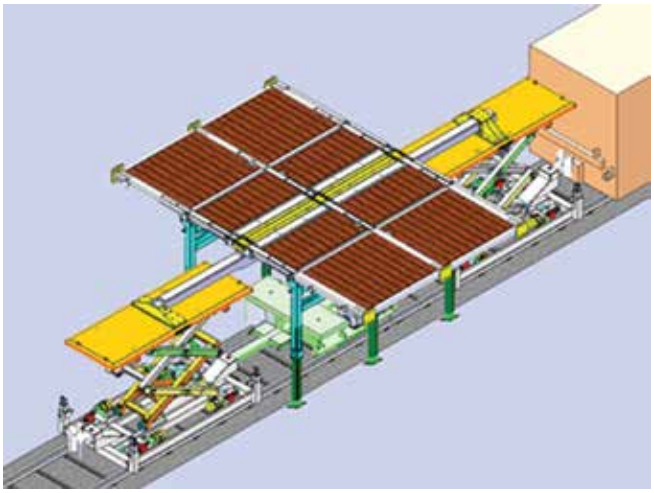
Methods of analysis.

Component	Method of analysis	Reinforcement
Thin shotcrete ring	Closed form analysis for tunnels in soft ground, horizontal load 50 percent of vertical.	#5 bars at 203 mm (8 in.) spacing (1 layer, centrally placed).
The lintel and sill deep beam	Strut and tie model (as per deep beam theory), plus moments and shears from the section above the lintel with no hoop load.	5 #10 bars each face main steel, chained #4 ties at 127 mm (5 in.) spacing.
Section above lintel with no hoop load	Designed as a slab with the thickened section of lintel acting as an edge beam.	
Jambs	Curved columns with uniform horizontal UDL as per normal jambs.	6 #4 bars each face main steel, #4 ties at 254 mm (10 in.) spacing.

FIG. 3

Portal and access adit development.





would have to be excavated simultaneously while several others would be undergoing waterproofing installation and final lining construction.

This was a new approach for the TFK team and the problems that needed to be overcome to make it happen were numerous and challenging. However, it was very clear that the driving tenet during cross passage planning would be "Do not stop the TBM," which created many of the challenges that had to be overcome.

TABLE 2

Difference between hand calculations and FE model.

Value	Hand calculation	Model	Difference
Maximum moment in shell	31 kNm/m	34 kNm/m	10%
Lintel moment	181 kNm/m	190 kNm/m	5%
Lintel tension	1982 kN/m	1947 kN/m	2%
Jamb compression	1982 kN/m	1892 kN/m	5%

Alignment and geology

The tunnel route comprises approximately 3,350 m (11,000 ft) of twin bore tunnel. The depth at the University of Washington Station is approximately 23 m (77 ft), and approximately 14 m (45 ft) at the Capitol Hill Station. The shallowest point in the tunnel has only 4 m (13 ft) of cover below the Lake Washington Ship Canal (Montlake Cut), and a deepest point of approximately 95 m (310 ft).

The soils encountered on the tunnel route comprise glacial and non-glacial deposits, the majority of which have been over consolidated by glaciation. The deposits consist of clays, silts, sands and gravels in varying proportions. Some of the layers form aquacludes, leading to a somewhat complex ground water profile. Water pressures on the lining vary from a minimum of 1 bar at crown, to a maximum of 6.5 bar at invert.

General layout

The TBM tunnel lining is a conventionally reinforced precast concrete lining, 5.74 mm (226 in.) internal diameter and 267 mm (10.5 in.) thick, with a ring length of 1.52 m (60 in.) comprising five segments plus a key, arranged in a trapezoid/parallelogram arrangement. Segments are bolted with spear bolts on the radial joints and push-fit dowels on the circumferential joints. Separate up and down rings are provided to assist in the negotiation of vertical and horizontal curves while maintaining the counter key segment below axis as much as possible.

There are 16 cross passages along the route at approximately 230-m (750-ft) centers. Typical cross passages have a maximum width of excavation of around 3.75 m (12 ft 4 in.), while two larger passages, for a sump and interconnection of Traction Electric conduit, go up to 5.1 m (16.8 ft). All of the cross passages require an opening two rings wide, within which a permanent opening support is cast. The opening requires temporary support from break-out until the permanent concrete has achieved its specified strength. The contract specifies that the temporary opening support to be the contractor's design.

A number of temporary services are installed along the length of the TBM tunnel, as shown in the typical tunnel cross section in Fig. 1, and need to remain in

almost continuous operation during cross passage excavation, except for short (less than one hour) interruptions in preparation for temporary support installation.

The design of the opening support also had to allow for the installation of pre support at each cross passage, consisting of a series of spiles over the top of the cross passage excavation profile.

Options and decisions

Temporary propping design had to accommodate continuous supply of the TBM with segments, utility pipe and rail sections and removal of excavated material via belt conveyor, by ensuring that the temporary support system did not conflict with the previously installed utility systems. The hamster cages were eliminated from consideration almost immediately, as their use presented numerous conflicts with the existing utilities, conveyor structure and the requirement to maintain continuous train traffic in the tunnel. After eliminating the hamster cage option, Halcrow started looking at the steel doorframe in detail. Early evolutions of the doorframe design were very heavy and required a high quantity of large diameter anchors to be drilled into the segmental lining around the opening. While technically feasible, the cost to fabricate 10 complete cross passages worth of support was prohibitive, as were the costs associated with the installation and removal of the large diameter anchors. It was at this stage that the designers and contractors sat down together to try to identify a better solution. Following extensive discussion of the constraints of the problem and possible ways around them, the discussion yielded the third, and ultimately the chosen temporary support system, which relied on a reinforced shotcrete shell placed inside the segmental lining around the cross passage opening. A similar system had been successfully implemented on a project in the United Kingdom several years before and appeared to be appropriate for this situation.

Shotcrete shell option. The shotcrete shell concept is similar to the shotcrete opening support that would be provided for a cross passage opening in the SCL lining for a conventionally mined tunnel, except that it supports the two rings of the broken out lining. The concept is illustrated in Fig. 2.

This solution offers a number of significant benefits over the jamb and lintel solution:

- The shotcrete is designed only for temporary loads and is, therefore, much thinner and more flexible than the segmental lining.
- The concrete is predominately in compression, so reinforcement levels are low (except around the opening).
- Service relocation limited to blocking out existing lines by 25 mm (6 in.).

FIG. 4

Top heading and bottom bench excavation.



- No relocation of the conveyor was required, and could be protected from the installation with a plastic sheet.

The relatively low cost of the propping system enabled TFK to have propping in place at every cross passage in both tunnels at the same time.

Design

The design of a novel solution such as this needs careful consideration to ensure that the structural behavior is understood and correctly accounted for in the design. The first step is to understand how the segmental lining is loaded by the ground. Prior to cross passage breakout the shell only supports self weight. No deformation of the permanent lining is expected in the short term (prior to breakout), so no load will be exerted on the shell. Some shrinkage may lead to a small gap between lining and shell.

Once the rings are broken out, hoop force in those rings is removed and all ground load on those rings will be transmitted directly through the segments onto the 127-mm (5-in.) shell inside. The shell then acts as a hoop, transferring hoop around the ring, with load transfer around the opening being provided in a 305-mm (12-in.) thickened section.

Loading. The magnitude of the loading might, at first glance, appear straightforward. This kind of opening is often designed on the basis of the pressures required to ensure a stable tunnel, such as those recommended by Terzaghi, which are easy to calculate and design for. However, these pressures were primarily derived from field observations of conventional tunneling using steel

sets, which allow significant relaxation of the ground — and hence reduction in load — prior to installation of the lining. Modern TBMs are specifically designed to limit this movement in order to control settlement, so there is potential for higher loads to be present in the lining. The authors are aware of instances of the grout load pressures essentially becoming 'locked in' to the lining. Furthermore, the presence of cohesive ground also increases the risk of loads significantly above those that would be predicted by Terzaghi in the medium term, which presents further risk if the cross passage excavation occurs significantly behind the TBM.

To address these risks, the design assessed how much movement of the lining would be required to alleviate the load to manageable levels. Using an axisymmetrical finite element model of the tunnel, it was shown that the load would reduce to manageable levels with relatively small inward displacements of the order expected with the shell (ignoring the beneficial effects of shrinkage), but that further movement would provide much less further alleviation of load.

FIG. 5

Placing dry mix shotcrete in crown.

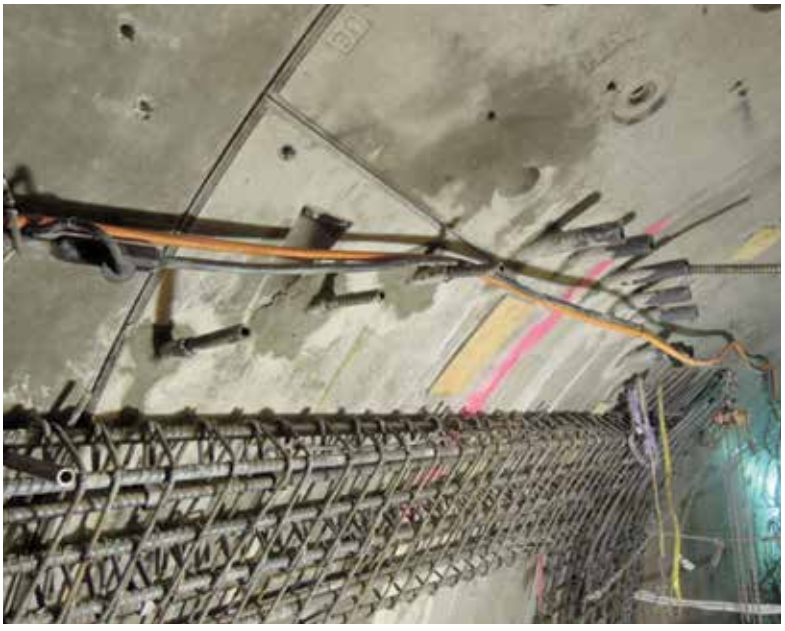


Design

With reference to Fig. 2, it can be seen that the design can be broken into a number of component parts that each lend themselves to simple analysis by hand calculation, as presented in Table 1.

FIG. 6

CP 19 pre-support spiles above lintel cage.



Due to the rather novel nature of the design, additional analysis was undertaken using a 3D plate model to verify that all behavior of the system was adequately understood. The finite element model was generally within 10 percent of the hand calculations (see Table 2), which was considered to be very good agreement. In particular, the deep beam behavior of the lintel and sill area was clearly visible in the model, including the slab action of the area with no hoop load. Nevertheless, the modeling did pick up a number of minor unforeseen effects, including:

- Torsion in the jambs. This arises because the inside of the jambs is not supported by the soil. This torsion was within capacity of the section and was verified by hand calculation.
- Longitudinal bending moments between the loaded and unloaded sections of the thin section. These arose in the model because the loaded sections were in compression and moved in, while the unloaded sections inside the intact rings did not move in. There was some doubt as to whether these would occur in reality due to the small relative displacements and effects of cracking. Nevertheless, they were checked and found to be within capacity.

The conclusion of the modeling was that the hand calculations would result in a design

that is robust without being conservative. It also identified the need to undertake a torsion check on the jambs when the jambs are only partially supported by the ground behind. However, it is the authors' view that finite element modeling would demonstrate lower levels of torsion, and is, therefore, recommended if hand calculations were to indicate that additional torsional reinforcement was required.

FIG. 7

Lintel beam removal.



Construction

Prework. Installation methodology evolved as TFK's crew became more familiar with the process and were able to refine it. Propping installation boiled down to three basic steps:

1. Segment preparation.
2. Reinforcing steel and formwork installation.
3. Shotcrete placement.

Perhaps the biggest concern about the shotcrete propping system was the impact that a shotcrete shell might have on the finished surface of the TBM tunnel lining; but the shotcrete also had to adhere to the lining during spraying while still being easy to remove. TFK performed a series of tests on a small mockup section of tunnel lining to confirm the suitability of a number of different methods to cover the segment joints and bolt pockets including backer rod, custom cut foam pieces, various tapes and thin plywood sections and multiple bond breaker products and installation procedures. Shotcrete was applied over the mockup and allowed to cure prior to removal. While actual shotcrete removal from the mockup proved to be significantly more difficult than anticipated, it did result in a clean final lining surface. The solution settled upon relied on 3-mm (0.125-in.) plywood sections nailed over the bolt pockets and a double layer of bondbreaker applied over the full area of the propping and a single layer applied one ring either side of the propping to ease removal of overspray. It was determined that excessive adhesion to the radial and longitudinal joints was not a significant concern.

Equipment. In order to make use of the unique propping solution and progress cross passage excavation concurrent with TBM mining, a custom folding work deck and a scissor-car-based work deck delivery system were devised and fabricated. The work decks and scissor car were designed by Kelley Engineered Equipment (KEE) of Omaha, NE. KEE also fabricated the scissor car while Traylor Bros., Inc. equipment shop in Evansville, IN fabricated the work decks. The decks are illustrated in Fig. 3.

Work sequence. TBM mining was conducted 24 hours per day, five days per week with maintenance performed on the weekends, while cross passage works were 24 hours per day, six days per week. The initial plan was to commence cross passage excavation from the Southbound tunnel after the trailing gear of the Northbound TBM (which was trailing Southbound by one month) had cleared the third cross passage along the alignment; roughly four months after the start of TBM mining. In reality, it took much longer to get ready for cross passage excavation than anticipated and, thus, true excavation did not begin until seven months after the start of TBM mining.

Throughout the propping installation process, the basic reinforcing steel detail remained unchanged — the radial and longitudinal steel in the thinner shell section was shipped loose and installed piece by piece while the reinforcement for the thickened section around the cross passage opening was separated into four cages that were pre-assembled off site and set in place. A series of hangers and slab bolsters were used to provide appropriate clear cover against the segmental lining and adequate support to hang the cages. The completed reinforcement, platform and services are illustrated in Fig. 4.

In order to provide shotcrete at relatively short notice and avoid obstructing the tunnel, the dry mix method was required. Dry mix shotcrete was delivered to the job site in one-cubic-yard super sacks and transported to the cross passage work via flat car and locomotive, before being placed by hand to the required profile as shown in Fig. 5.

Coordination with cross passage pre-support requirements (including dewatering). The flexibility of the open-

FIG. 8

Conveyor side shell removal.



ing support being shotcrete was realized in the following:

- Pre-support spiles installed through the segmental lining over the crown of the cross passage, which were installed prior to the installation of propping to avoid conflicts between the propping reinforcing steel and the spiles. This is illustrated in Fig. 6.
- Dewatering wells that were routed through the propping reinforcing cages and shotcrete without causing interference.
- Post-installed dewatering wells, which required core drilling 25-mm (6-in.) diameter holes through the propping sill beam and reinforcing cage.

Movements and monitoring results. Overall, the shotcrete propping performed admirably and did not exhibit large movements or deformations. In a limited number of instances, total movement approached the trigger levels identified by Halcrow in the design documents but never reached a level of real concern.

Method of demolition. The project schedule required that temporary propping be in place in tunnels and at all 16 cross passages until very late in the job, requiring an efficient demolition methodology be developed and implemented. This exercise was made more difficult due to the unknowns in how the shotcrete would behave during the demolition process. Despite this complexity, an effective methodology and sequence were arrived upon during the second demolition attempt. The primary demolition tool is a Gradall XL 4300 armed with a 2,500 ft-lb hydraulic demolition hammer. A second excavator (Cat 304), with a hydraulic hammer, bucket and thumb was also used to assist with the breaking operations and perform debris load out, with an excavator situated on either side of the cross passage and appropriate protective devices in place around the utilities.

The demolition procedure begins by breaking out a 1.2-m (4-ft) wide swath of the shell section along the full 6.1-m (20-ft) length of the crown. This creates relief and allows the remaining demolition to occur rapidly. The excavators next break the bond between the shell and segmental lining shell section on the non-cross passage side of the tunnel and then pull the shell section off the wall in several large pieces, as illustrated in Fig. 7. The large pieces are processed, sorted and loaded out before additional demolition occurs. Next, a relief cut is made across the columns on the cross passage side roughly 0.6 m (2 ft) below the lintel cage, after which the large machine breaks the lintel cage free from the segmental lining and it falls off in one large section, as illustrated in Fig. 8. The two columns are broken down traditionally to the top of the sill beam, and the sill beam and invert portion of the propping are removed in a follow-on operation when there is good access for rapid completion of the invert concrete across the propping width.

A follow-on finishing operation is required to remove overspray, plywood covers and miscellaneous anchors and repair any surface damage inflicted during the demolition process. This work is performed by hand and is accessed off scissor lifts working on the tunnel invert.

Conclusion

The opening in the shotcrete shell behaves as a deep beam above and below the opening and, while a number of effects need to be considered in design, hand calculations will usually suffice. Finite element modeling is only likely to offer savings in reinforcement where torsion in the jambs is an issue.

Use of the shotcrete shell approach to temporarily support around cross passage openings permitted TFK to start cross passage work earlier and concurrently execute the work on more fronts than would have been possible with a more traditional method of temporary support. Without these advantages the project could not have been completed within the tight schedule demands outlined in the contract.

Finally, the project highlights the inescapable value of focused face-to-face discussion, without which it is doubtful if the solution described would have come to light. ■

FEATURE ARTICLE

UCA's North American Tunneling conference set for Los Angeles

The Underground Construction Association's (UCA) 2014 North American Tunneling (NAT) conference is expected to attract about 1,000 tunneling and underground construction professionals. With the theme "Mission Possible," attendees from around the world will hear the latest in tunneling and underground construction technology in the two-and-a-half days of technical sessions.

The meeting is scheduled for June 24-27 at the JW Marriott Los Angeles Live in Los Angeles, CA. In addition to the technical programming, the accompanying exhibit has attracted 143 exhibitors in 162 booths. And the conference will offer short courses and plenty of social activities that will provide attendees the opportunity to catch up with each other. In addition, a proceedings volume containing all of the 128 papers will be available.

An impressive lineup of sponsors will help attendees enjoy the conference. They include Brierley Associates, Kiewit Infrastructure Group, Parsons, Skanska, Traylor Bros., MWH and HNTB.

Short courses

Four one-day short courses are scheduled for Sunday, June 22. Seven professional development hours will be awarded for each. "Tunnel construction ventilation planning design" will be taught by Brian Prosser and J. Daniel Stinnett, both from Mine Ventilation Services. The first half of the workshop will be devoted to the fundamentals of ventilation, basic thermodynamics, fan selection and other parameters essential to the understanding of tunnel ventilation. The second half of the workshop will be devoted to the design of ventilation systems, selection of equipment and system simulation using standard simulation tools/programs.

This course will provide an outline of the elements of modern thinking involved in the planning, design and control of construction ventilation circuits. It will also discuss new technologies in ventilation monitoring and control systems.

"Surveying in the tunneling industry" will be presented by Peter DeKrom, Atkins; and Darrell Bartley, Subterranean Solutions. This course is designed for engineering interns or individuals with a strong mathematics background interested in putting math in motion. Tunnel surveying is frequently ignored or not considered as a key element in tunnel construction. Proper survey procedures should be implemented beginning at the design phase and continuing throughout all stages of construction. This course will cover survey datums: geodetic datums versus localized datums and surface control, precision surveying for tunnel boring machine (TBM) guidance, guidance systems, as-built surveys (scanning technologies) and latest technologies to implemented.

About 1,000 attendees are expected at NAT this year.



The third course is "Hyperbaric operation in earth pressure balance tunneling, current standards and operational requirements," presented by Kevan Corson, Poseidon Safety International. The application and utilization of alterations in atmospheric pressure dictate that the safety and operational personnel comprehend the beneficial and potentially hazardous aspects of this esoteric environment. Applicable gas laws and their role in hyperbaric operations will be reviewed. This course covers the safety issues with the use of hyperbaric oxygen in the prevention of decompression injuries in the compressed air worker. Objectives covered include compression barotraumas, oxygen seizure, decompression barotraumas, tender decompression, emergency egress and fire. Also discussed will be the current regulations that govern the

Steve Kral,
Editor

operational and safety aspect of compressed air work.

"Grouting in underground construction" will be presented by Raymond Henn, Brierley Associates; and Paul Schmall, Moretrench. This course will provide an overview of the materials, equipment and various grouting methods used in association with underground construction and tunneling in soils and rock. Subjects covered will include cements and admixtures, grouting equipment and practices, chemical and cementitious permeation grouting, jet grouting, compaction grouting, pre-excavation grouting, backfill and contact grouting, and cellular grouts. Nine industry experts will give the lectures on these various grouting subjects and techniques. Attendees will also receive a course notebook containing all presentation material by the speakers. This course is recommended for contractors, engineers, owners and consultants involved in any aspect of underground design and construction.

Technical program

NAT 2014's technical program will feature 20 sessions discussing all aspects of the tunneling and underground construction industry. A few of the topics include case histories, planning, design and technology. Abstracts of the presentations will be provided in the pocket program that will be available at the meeting. In addition, short profiles of the exhibiting companies are provided in the NAT Showguide that is bound into this issue of Tunneling & Underground Construction.

Monday, June 23 — Eight sessions are planned for the day. Morning sessions include Case studies: Ground treatment/control, chaired by W. Dean, Frontier-Kemper; Design: Design of underground spaces, chaired by M. Torsiello, Jacobs Associates; Planning: Project delivery I – Design and management, chaired by I. Hee, Arup; and Technology: Operation monitoring and control, chaired by M. Bruen, MWH Global.

Afternoon sessions include Case studies: Water control/grouting, chaired by D. Penrice, Hatch Mott MacDonald; Design: Challenging design issues, chaired by D. Hamilton, Kiewit Infrastructure; Planning: Risk and cost management, chaired by B. Harris, Drill Tech Drilling and Shoring; and Technology: Ground support, final lining and design, chaired by H. Leindecker, Halcrow.

Tuesday, June 24 — The sessions scheduled for Tuesday morning include Case studies: NATM/SEM contracting methods, chaired by S. Rand, King Packaged Materials; Design: Ground movement and structures analysis, chaired by A. Nitschke, Gall Zeidler Consultants, and G. Davidson, Jacobs Associates; Planning: Geotechnical and third party planning, chaired by S. Harvey, Brierley Associates; and Technology: TBM technology and selection, chaired by B. Robinson, Traylor Brothers.

Afternoon sessions include Case studies: Rock tunnels, caverns and shafts, chaired by M. Stokes, Skanska USA Civil NE; Design: Water and waste water conveyance, chaired by J. Bednarski, MWD; Planning: Project deliver II — design/build, chaired by M. McKenna, LACMTA; and Technology: Innovative toolbox, chaired by C. Fleming, Michels.

Wednesday, June 25 — The NAT technical program concludes Wednesday morning with four sessions. They include Case studies: Mechanical excavation, chaired by B. Zelenko, Parsons Brinckerhoff; Design: Design of transit tunnels, chaired by J. Theodore, Sound Transit; Planning: Future projects and industry trends, chaired by D. Haug, LASCD; and Technology: Fresh approach on performance, chaired by J. Wonnenberg, EPC Consultants.

Social events, awards

Monday's NAT luncheon speaker will be Char Miller, Director, Environmental Analysis Program and W.M. Kreck Professor of Environmental Analysis, Pomona College. The UCA of SME/ITA breakfast will be held Tuesday morning. Its program includes presentations from the winners of the Student Paper Contest. An exhibit hall luncheon on Tuesday and a reception later that afternoon are scheduled.

The UCA of SME Awards Banquet will take place Wednesday evening. Three industry professionals will be honored at the banquet, along with the UCA's Project of the Year (see pages 28-30 of this issue).

Herbert H. Einstein, professor at the Massachusetts Institute of Technolgy, will receive the UCA's Outstanding Educator Award. In underground construction, he developed several analysis and design approaches for tunneling in swelling rock. He and is co-workers also developed the Decision Aids for Tunnels, with which cost, time and resources subject to uncertainties can be estimated.

The Lifetime Achievement Award will be presented to Ronald E. Heuer, a geotechnical consultant. He has worked on more than 1,000 underground projects in the United States, Canada and several foreign countries. While working on Colorado's Eisenhower Tunnel in 1970, he helped develop concept drawings and geotechnical analysis for multiple drift methods used to complete tunnel excavation.

Lok Home, president of the Robbins Co., will receive the Outstanding Individual Award from the UCA. Prior to joining Robbins as a field service manager, he worked as a project manager for several Canadian mines. Home also founded Boretec Inc. He was instrumental in merging Boretec and Robbins in 1998 and remains its president.

The Project of the Year Award will go to the Tom Lantos project in San Mateo, CA. HNTB was chosen as the lead designer of the project, also known as the Devil's Slide project. The New Austrian Tunneling Method was used throughout the project to build the twin tunnels beneath San Pedro Mountain, greatly reducing commuter travel times and increased safety.

RETC is next year

While it is still a year away, make plans to attend the Rapid Excavation and Tunneling Conference (RETC) June 7-10, 2015, scheduled to be held in New Orleans, LA. ■

FEATURE ARTICLE

Risk related to PPP tunneling projects for design professionals

Tunnels and underground projects are inherently more risky than vertical projects, which typically utilize more conventional design and construction approaches and are undertaken in the context of relatively ascertained and defined conditions. On tunnel and underground projects, there are a host of special risk factors, including unknowns and uncertainties as to the physical and behavioral characteristics of the ground, the inextricable interdependence and necessary interaction of design decisions and construction means and methods with those ground conditions as well as the manner in which risks are allocated among project participants for unanticipated subsurface conditions. Public-private partnerships (PPP) projects, in their own respects (and independent of any major subsurface component), pose significant risk for all private sector participants. The main driver of owners to procure projects using PPP is financial, as often all, or substantially all, of the design and construction risk are transferred to the private sector consortium, including the design-build (D-B) team. For a concerning number of those public owners, that risk transfer regime includes rather onerous and aggressive contractual terms that allocate to the private sector participants substantially all risks associated with the encountering of unanticipated subsurface conditions. These aggressive risk allocation provisions, while directly impacting project participants upstream of the consulting engineer, have an indirect and corresponding risk intensifying effect upon consulting engineer professional liability exposure.

Tunnel fabrication at the Elizabeth River Tunnels project, a public-private partnership in Virginia. Photo courtesy of the Elizabeth River Tunnels Project.



There are many factors that result in increased professional liability exposure for consulting engineers involved in PPP projects. The more prominent and prevalent of those factors fall into the following categories:

Subsurface conditions risk allocation: Increasingly, project owners on major D-B and PPP subsurface projects are seeking to transfer substantial risk for subsurface conditions to the private sector participants (i.e. the concessionaire and the design-builder). Subsurface conditions, beyond any doubt, are a significant source of risk exposure, disappointed expectations, default and claims. For that reason, it is generally recognized that in order to ameliorate those concerns, the principles of fairness and balance in risk allocation should be adopted and implemented in the specific context of subsurface conditions.

Unfair risk allocation between the project owner and the concessionaire and/or design-builder will increase the risk of professional liability exposure for the consulting engineer. There appears to be no published empirical data conclusively establishing that use of these types of aggressive risk allocation provisions and related contracting practices in D-B and PPP agreements increases the risk of professional liability exposure for the consulting engineer. However, logic (and the experience of the authors) supports the conclusion that a design-builder is more likely to transform what would have been a contractual differing site conditions claim against the project owner into such a third-party professional liability claim – to recover costs incurred by the design-builder but not recoverable against the project owner due to aggressive risk allocation and disclaimer provisions in its prime contract.

Design development risk: For the consulting engineer, design development in D-B and PPP projects moves at an accelerated pace, and this schedule compression may often lead to liability exposures. The schedule compression of the design process of tunnels

David J. Hatem and Nasri Munfah

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and underground projects places special pressure on the geotechnical design discipline on which the design depends. The consulting engineer may be under significant pressure to produce work product resulting in insufficient data or inadequate levels of completion or coordination with other aspects of the design, thereby creating the risk of redesign during post-award or construction and the attendant increased costs and delays experienced in the construction process.

In addition, prior to contract award, the design-builder may look to the consulting engineer to provide quantity estimates and may seek to hold the consulting engineer accountable for overruns in cost or quantities. Although the concessionaire and the design-builder each assume (directly, or ultimately, to the project owner) the contractual risk and financial obligations associated with cost overruns due to "excess" quantities or other consequences of the post-award design development process, in many instances those parties regard the consulting engineer as a de facto risk partner and pass down these obligations. There is a further risk that the public owner may attempt to dominate the design review process, thereby resulting in delay and in the imposition of owner design preferences beyond the contractual requirements. Owner domination and imposition of preferences and judgments in the design development process in PPP and D-B projects is especially problematic in tunneling and underground projects in which the ability of the consulting engineer to make appropriate judgments and exercise discretion are critically important.

In a related vein, it should be noted that statements or descriptions of anticipated or assumed subsurface conditions, characteristics, or parameters in a geotechnical baseline report (GBR), as a general matter, are provided for the purpose of facilitating the allocation of risk between the project owner and the concessionaire and/or the design-builder. These types of statements or descriptions should not be understood by the design engineer as constraining, defining, prescribing or otherwise limiting (or, worse yet, relieving or substituting for) the engineer's obligation to exercise sound and independent judgment in the development of the design.

D-B and PPP design optimization and value engineering typically allow for input and collaboration from various professionals (including owner, concessionaire and design-builder) with the design engineer in the design development process in order to reduce project cost and/or to facilitate the construction process. While those are salutary objectives, the design engineer should be careful not to allow such input or collaboration to intrude upon its exercise of independent and sound professional judgment in the design process.

Cost overrun risk: A potential major risk for consulting engineers in D-B and PPP projects arises out of cost growth (above the guaranteed maximum price) due to the design development process. Typically, this type of claim arises when there are material differences between the design-builder's pre-award bid estimate assumptions (bid estimate) and the actual cost of designing and constructing the project. As a general observation, the design-builder's professional liability claims against the consulting engineer often seek recovery for some or all of its cost overrun.

A typical cost overrun involves some or all of the following factors:

- Aggressive, unrealistic and opportunistic preaward cost estimating or bidding.
- Inadequate information or design definition prior to the submission of the bid.
- Imposition of the project owner's design preferences that exceed contractually mandated design criteria or standards.
- Project owner's unwarranted intrusion into, or restriction of, the design-build team's discretion, judgment, or innovation or design responsibility (as engineer of record).
- Unanticipated or unreasonable application or enforcement of code or other public regulatory requirements or standards in the design development process.
- Inadequate design-builder contingency for cost growth due to design development.

Most of these factors have nothing to do with deficient service performance of the consulting engineer. Depending upon the terms of the prime design-build agreement, the design-builder may have limited, or no, opportunity to obtain an equitable cost or time adjustment from the project owner when some or all of these factors occurs. This situation often leads to a professional liability claim by the design-builder against the consulting engineer.

The bottom line is that unless the design-builder plans for, and is prepared to fund contingency for design development, in tunnel and underground projects there will often be gaps between pricing or bid assumptions and available financial resources required to address cost growth due to design development. The consulting engineer potentially will be exposed to significantly increased risk in D-B and PPP projects due to design development cost growth than in design-bid-build. In the contractual negotiation process, the design-builder may "flow down" various terms, the effect of which would be to transfer design development risk to the consulting engineer. These terms typically provide that:

- The design-builder has the right to rely upon the "accuracy" or "completeness" of conceptual or preliminary design and any quantity surveys, cost estimates or other work product prepared by the consulting engineer during the preaward phase.
- The consulting engineer will share in cost growth due to variations between pre-bid cost and quantity estimates and post-award actual costs and quantities based on the final design.
- The design-builder has the opportunity to influ-

ence or constrain design development cost through "design to cost," "design optimization," "collaborative design processes" and "value engineering" approaches.

The consulting engineer certainly should endeavor to manage its liability risk exposure for design development cost growth through provisions in its subconsultant agreement with the design-builder, such as those excluding or limiting responsibility for cost or quantity estimates. While these provisions, if contractually accepted, will likely provide the basis for an effective defense to professional liability claims arising out of cost overrun risk, the reality is that many design-builders, especially in current economic conditions and competitive market, do not agree to such provisions.

An alternative approach to managing design development risk is for project owners and design-builders (and/or concessionaires) to each carry adequate contingency for cost growth due to design development and prudent risk sharing including the utilization of GBR and contingency funding plan as was demonstrated by the Port of Miami and the Alaskan Way (SR99) tunnels.

Heightened performance standards: On most projects, a consulting engineer is required to perform its services in accordance with reasonable skill and care required under the circumstances. However, in many PPP projects, the design-builder and, by extension, its consulting engineer are obligated to provide certain services in accordance with a "fitness for purpose" obligation. Under the latter obligation, the engineer is required to produce a design that meets specific client requirements, and adherence to reasonable skill and care will not necessarily provide a defense or justification for failing to meet those requirements. In addition, "fitness for purpose" performance standards raise issues as to whether liability determined to exist under such a standard falls within the scope of coverage afforded under standard professional liability insurance policies.

Conclusion

PPP of tunneling and underground projects represent the potential for substantial risks for consulting engineers. The same salutary principles of fairness and balance in risk allocation should apply in the context of PPP projects. ■

COMING EVENTS

Colorado School of Mines to host shotcrete course

Shotcrete, a comprehensive three-day short course, will be held Sept. 3-5, 2014 at the Colorado School of Mines (CSM) in Golden, CO. The course director is Raymond Henn, adjunct professor at CSM. Attendees will explore effective and sustainable uses of shotcrete. Economical and expedient, shotcrete is increasingly used for the support of excavation, geotechnical retaining walls, soil nails, underground construction and tunneling, mining, new structural walls and wall repair.

Attendees will receive two continuing education units upon completion of the course. Registration is now open online. Enrollment is limited and applications will be accepted in the order received. The course fee is $1,585 through July 29, 2014 and $1,685 thereafter. Opportunities to become course sponsors at various levels are available online as well. For more information, registration forms and a detailed course outline, visit www.csmspace.com/events/shotcrete. ■

UCA of SME

George A. Fox Conference
Jan. 27, 2015
Graduate Center
City University of New York
365 Fifth Ave.
New York, NY 10016

Cutting Edge
Nov. 2-4, 2014
The Westin New York
at Times Square
270 W. 43rd St.
New York, NY 10036

FOR ADDITIONAL INFORMATION CONTACT: Meetings Dept., SME 800-763-3132, 303-948-4200
fax 303-979-4361, email sme@smenet.org

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	Under design
Water Tunnel #3 Stage 3 Kensico	NYC-DEP	New York	NY	Water	84,000	20	2017	Under design
Cross Harbor Freight Tunnel	NYC Reg. Develop. Authority	New York	NY	Highway	25,000	30	2016	Under study
Silver Line Extension	Boston Transit Authority	Boston	MA	Subway	8,400	22	2018	Under design
South Conveyance Tunnel	City of Hartford	Hartford	CT	CSO	16,000	26	2015	Under design
Red Line Tunnel - Cooks Lane Tunnel	MD Transit Administration	Baltimore	MD	Subway	14,000	22	2015	Under design
Red Line Tunnel - Downtown Tunnel	MD Transit Administration	Baltimore	MD	Subway	36,000	22	2015	Under design
Purple Line - Plymouth Tunnel	MD Transit Administration	Baltimore	MD	Subway	1,000	30x40	2015	PPP - RFQ 10/22/14
Northeast Branch Tunnel Northeast Boundary Tunnel	DC Water and Sewer Authority	Washington	DC	CSO CSO	11,300 17,500	15 23	2018 2021	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
Dugway Storage Tunnel	NEORSD	Cleveland	OH	CSO	16,000	24	2014	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
Big Creek Storage Tunnel	NEORSD	Cleveland	OH	CSO	19,500	20	2026	Under design
Ohio Canal Interceptor Tunnel	City of Akron	Akron	OH	CSO	6,170	27	2015	Under design
Northside Interceptor Tunnel	City of Akron	Akron	OH	CSO	6,850	24	2021	Under design
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

TUNNEL NAME	OWNER	LOCATION	STATE	TUNNEL USE	LENGTH (FEET)	WIDTH (FEET)	BID YEAR	STATUS
Lower Pogues Run	Indianapolis DPW	Indianapolis	IN	CSO	9,700	18	2018	Under design
Fall Creek	Indianapolis DPW	Indianapolis	IN	CSO	19,600	18	2016	Under design
White River Tunnel	Indianapolis DPW	Indianapolis	IN	CSO	27,800	18	2016	Under design
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	Under design
East Link Light Rail Extension	Sound Transit	Seattle	WA	Transit	30,000	22	2016	RFQ underway
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 2015 2017	 Awaiting award 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	2014	RFQ underway
River Supply Conduit - Units 5 and 6	LA Dept. of Water and Power	Los Angeles	CA	Water	8,608	12	2014	W.A. Rasic low bidder
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
SVRT BART	Santa Clara Valley Trans. Authority	San Jose	CA	Subway	22,700	20	2014	Under design/ delayed
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	Sacremento	CA	Water	3,500	20	2018	Under design
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
Combined Sewer Storgage - East-West	City of Ottawa	Ottawa	ON	CSO	14,400	10	2015	Under design
Combined Sewer Storgage - North-South	City of Ottawa	Ottawa	ON	CSO	5,300	10	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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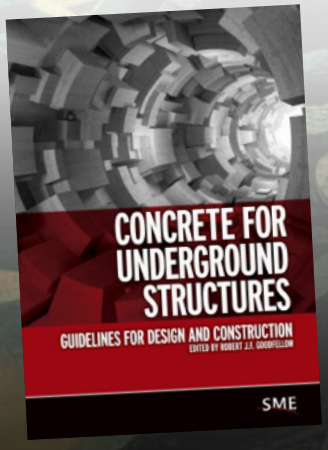
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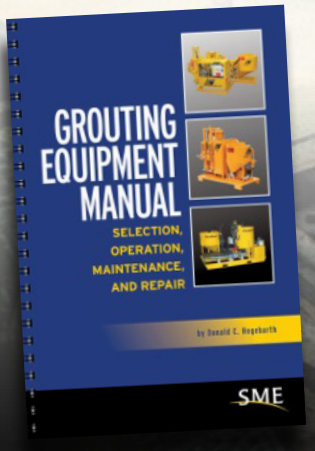
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EXECUTIVE COMMITTEE

Four members join the UCA Executive Committee at NAT

Four members of the UCA Division of SME will join the division's Executive Commttee during the North American Tunneling Conference June 23-25, 2014. They are Leon (Lonnie) Jacobs, Colin Lawrence, Michael Mooney and Michael Rispin. They will serve until June 2018.

Leon Jacobs

Leon (Lonnie) Jacobs has more than 30 years of experience in heavy civil and underground construction in the New York metropolitan area.

Jacobs earned a B.S. cum laude in civil engineering from Northeastern University, Boston, MA, in 1985, and an M.S. in construction management from Brooklyn Polytechnic University in 1988.

After graduation, Jacobs held several engineering positions on the New York City Third Water Tunnel project. In 1988, he worked for Perini as a project engineer on transit and waste water projects in the New York City region until joining Frontier-Kemper in 1995.

Some of the projects Jacobs has constructed with Frontier-Kemper during the past 19 years include: the New York City Department of Environmental Protection Water Tunnel Shaft 26B, the 26th Ward Water Pollution Control Plant Pilot Program, the New Croton Aqueduct Rehabilitation Project, the TBTA Queens Midtown Tunnel Rehabilitation Project and the New Jersey Transit Hudson Bergen Light Rail Weehawken Tunnel/Bergen Line Avenue Station Project.


JACOBS

Jacob's professional responsibilities at Frontier-Kemper have covered all facets of heavy construction, from project management to engineering, and include experience in design, scheduling, cash flow, insurance, safety, accounts payable and receivable, payroll, estimating, budget production, risk management, quality control, change-order negotiation, customization of equipment, design of specialized equipment, value engineering, human resources and strategic planning.

Jacobs has served on the George A. Fox Conference Committee since 2007 and was chair in 2008 and 2009. He has just begun a second, two-year term as the Fox Conference chair. He is a member of the UCA's North American Tunneling Conference (NAT) planning committee and helped organize NAT in 2012 and 2014. He will be vice chair of the NAT in 2016 when it is held in conjunction with the World Tunneling Conference. He is a licensed professional engineer in New York, New Jersey, Maryland and Virginia. He is also a member of Chi Epsilon, The Moles, the New York State Society of Professional Engineers and the American Society of Civil Engineers.

Colin Lawrence

Colin Lawrence is Hatch Mott MacDonald's tunnels practice leader for North America and a senior vice president with the firm. He has more than 34 years of specialized experience in all types of tunneling for transportation, water and wastewater projects through a variety of challenging ground conditions. He resides and has worked in the United States for the last 15 years.

Having worked for an owner and consultants, Lawrence has experience in all aspects of underground project implementation, from planning, design and project management to construction management and project completion.


LAWRENCE

He was fortunate to be involved in some of the more technically challenging and high-risk tunnel projects around the world. These included all types of tunnel projects for transportation, water, wastewater, oil and mining in a variety of challenging ground conditions in soil, rock and mixed face conditions.

Mike Mooney

Mike Mooney is a professor and the Grewcock chair in underground construction and tunneling (UC&T) at the Colorado School of Mines. He leads the university-wide interdisciplinary Center of Excellence in Underground Construction & Tunneling and serves as director of the UC&T graduate degree program at Mines.

Mooney is a licensed professional engineer and has 20 years of academic and consulting experience in civil engineering and construction.

(Continued on page 30)

UCA AWARDS

UCA presents four awards at NAT

Outstanding Educator Award to Herbert H. Einstein

The UCA of SME's Outstanding Educator Award is presented by the UCA Executive Committee to professors and teachers who have had an exceptional career in academia and education in the areas of underground design and construction. These individuals also have made significant contributions to the industry through their academic interests, as well as through the introduction of many student graduates into the industry. They are nominated by their peers.

Herbert H. Einstein, a professor civil and environmental engineering at the Massachusetts Institute of Technology, received his Dipl. Ing. and Sc.D. in civil engineering from ETH-Zürich. His teaching and research areas are in underground construction, rock mechanics and engineering geology. Einstein has been involved as an advisor, consultant and researcher in issues related to underground construction, rock mechanics and rock engineering and natural hazards, notably landslides and in waste repository problems. He has been and is member of a number of national and international technical-scientific committees and advisory boards.


EINSTEIN

Einstein is also co-editor of the journal, *Rock Mechanics and Rock Engineering* and member of the editorial boards of *Tunnelling and Underground Space Technology* and of *Engineering Geology*. Einstein is the author or co-author of more than 240 publications in his area of expertise. He received the Müller lecture award from the International Society for Rock Mechanics and received the Outstanding Contributions to Rock Mechanics award from the American Rock Mechanics Association. He has also received several teaching awards from his department and from the School of Engineering.

In underground construction, Einstein developed several analysis and design approaches for tunneling in general and tunnels in swelling rock specifically. In addition, he and his co-workers developed the Decision Aids for Tunnels, with which cost, time and resources subject to uncertainties can be estimated. These analysis, design and construction management tools have been applied to a number of tunnels worldwide, ranging from transportation tunnels to underground-waste storage facilities.

Lifetime Achievement Award to Ronald E. Heuer

The UCA Lifetime Achievement Award recognizes outstanding achievements in the underground design and construction industry. The outstanding achievements recognized have been accomplished through the design or construction of civil underground facilities.

Ronald E. Heuer is an independent geotechnical consultant who works almost exclusively on underground projects. He received a B.S. degree in civil engineering (1963), an M.S. in geology (1965), and a Ph.D. in civil geotechnical (1971) from the University of Illinois, Champaign-Urbana (UI).

Upon graduation, he joined A.A. Mathews Inc., a construction engineering firm in the Los Angeles, CA and Washington D.C. areas. He returned to UI for three years to teach undergraduate and graduate courses in geotechnical engineering, while continuing to work part-time consulting on tunnel projects.


HEUER

Since 1978, he has worked full time as an independent consultant, about three-fourths of the time for contractors and one-fourth of the time for owners and engineers. Prior to construction, his work involves the study of available geologic information to interpret expected ground behavior and potential water problems and evaluating the suitability of alternative construction methods. During construction, he gets involved in interpreting the cause of problem behavior of ground and water and developing solutions.

Heuer has worked on more than 1,000 underground projects and tunnels throughout the United States, Canada and in a number of foreign countries. He has witnessed the transition from conventional drill-blast excavation in rock and compressed air hand mined shields in soft ground to today's hard rock TBMs and pressurized face soft ground machines. He has seen the introduction of precast concrete segments, shotcrete, and SEM methods into the United States.

Some special projects include Colorado's Straight Creek Tunnel in 1970, the Eisenhower Tunnel

first bore. There, under Al Mathews' guidance, Heuer developed concept drawings and geotechnical analysis for the multiple drift methods used to complete tunnel excavation through the squeezing Loveland Fault Zone at 305 m (1,000 ft) depth. Other projects were the Point Lepreau cooling water intake shaft in New Brunswick, Canada in 1977, where a 6.4 m (21 ft-) diameter shaft excavation in rock was raised to within 4.3 m (14 ft) of the ocean bottom under the Bay of Fundy and the Crosstown Tunnel in Milwaukee, WI in 1986, where a 9.6-m (32-ft) diameter TBM using rock dowel support was driven with only 5.5 m (18 ft) of poor rock cover below a buried valley full of waterbearing sand and gravel under a 76-m (250-ft) water head.

Heuer served as chair of the second Dispute Resolution Board in North America on the Seattle Mt. Baker Ridge Tunnel in late 1980s. He also worked on the Big Walnut Augmentation/Rickenbacker Interceptor Tunnel in Columbus, OH in 1999, where earth-pressure-balance tunnel excavation was successfully completed through boulder ground; the Arrowhead Tunnels near Los Angeles, which were completed in waterbearing faulted ground adjacent to the San Andreas Fault under water heads up to 305 m (1,000 ft); and the recently completed Queens soft-ground tunnels excavated by slurry TBM methods at shallow depth under a railroad switchyard. On some of these he was actively involved in design or construction. On others, his contribution was to review proposed methods.

Outstanding Individual Award to Lok Home

The Outstanding Individual Award recognizes those individuals who have made significant contributions to the field of tunneling and underground construction and to UCA.

Lok Home is president of The Robbins Company in Solon, OH. He began his more-than-45-year career in the tunneling and mining industry after graduating with a degree in mining technology from the Haileybury School of Mines in Ontario, Canada. Between 1965 and 1968, he worked as a project manager at several Canadian mines, before joining The Robbins Company as a field service manager.



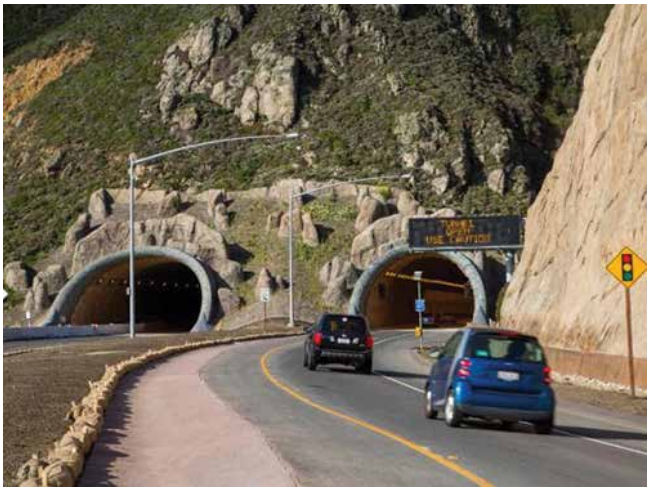
HOME

Home served as president of Atlas Copco Jarva from 1980 to 1985, then founded Boretec Inc. Boretec later acquired Robbins in 1998 and unified the two companies under the Robbins name. Today, The Robbins Company is a worldwide manufacturer of tunnel boring machines and underground equipment with 12 international subsidiaries and representation in more than 35 countries.

Project of the Year Award to the Tom Lantos Tunnel project, San Mateo County, California

The Project of the Year Award recognizes an individual or a group that has shown insight and understanding of underground construction in a significant project, which may include a practice, developing concepts, theories or technologies to overcome unusual problems within a project.

For more than 30 years, land slippages and rockslides plagued the narrow, cliff-side stretch of U.S. Highway 101, aptly named as Devil's Slide. After a heavy winter rain, residents of Pacifica and Half Moon Bay, CA, would wake up wondering if the highway they depended on daily still would be there, or if it had slid once again into the Pacific Ocean. Notorious for rock slides and collapse, a section of scenic State Route Highway 1 was closed nine times in the past 28 years, with the longest closure lasting 158 days.



UCA AWARDS

After years of public input and careful evaluation, HNTB was chosen as the lead designer on the project for the California Department of Transportation. Constructed beneath San Pedro Mountain using the New Austrian Tunneling Method, the project lies along the active San Andreas Fault, with four inactive faults crossing the tunnels.

The tunnels feature HNTB's innovative double lining — an initial layer strengthened with synthetic shotcrete to meet deflection requirements and a final layer that accommodates potential movements. The design meets some of the toughest seismic specifications in the world.

The twin tunnels are 9 m (30 ft) wide by 6.8 m (22.3 ft) high and 1.3 k (4,200 ft) long. The $430 million project includes the two tunnels, a 305-m (1,000-ft) bridge that spans the valley at Shamrock Ranch, and an intelligent transportation system that carefully monitors and reports road conditions and environmental changes in the region. The Tom Lantos Tunnels are named after the late Congressman Tom Lantos, who was instrumental in securing funding for the project. The tunnels opened on March 26, 2013. The county plans to open the old highway to hikers and bicycles in 2014. ■

EXECUTIVE COMMITTEE

(Continued from page 27)

He received a B.S. in civil engineering from Washington University in St. Louis, an M.S. in civil-structural engineering from the University of California-Irvine and a Ph.D. in civil-geotechnical engineering from Northwestern University. His expertise lies in soft-ground tunnel design and construction, instrumentation/monitoring of construction systems and equipment, nondestructive imaging techniques and intelligent geoconstruction processes. He has been the principal investigator for more than 30 geoconstruction-related research projects and has written more than 100 technical publications.


MOONEY

Mooney teaches courses in tunnel design and construction, support of excavations/earth retaining structures, instrumentation and monitoring, nondestructive evaluation, and intelligent geosystems. He has mentored more than 25 M.S. and Ph.D. students to completion of their theses and currently advises graduate and undergraduate students pursuing industry-focused, applied research projects.

In addition to the UCA Executive Committee, Mooney serves on the American Society of Civil Engineers' underground engineering committee, the ISSMGE underground construction in soft ground committee and the International Tunneling Association committee on education and training.

Michael Rispin

Michael Rispin was born in Montreal, Canada in 1961. He received his bachelors degree, B.Eng. Mining, in 1985, along with a minor in management.

Rispin began his career as a technical representative in the field of explosives application and, during the next 12 years, worked his way into various management positions. Throughout this period, he was primarily involved with underground applications in mining and tunneling construction.

In 1996, Rispin shifted his focus to construction chemicals. He began by propagating the benefits of sprayed concrete (wet mix shotcrete) technology to North American mining. He progressed through various positions in his company, Master Builders, which was subsequently acquired by BASF. He accepted an assignment in Switzerland with BASF and focused almost exclusively tunneling and underground mining, domestic and international.


RISPIN

Since 2009, Rispin has been part of the Normet Group and is currently senior vice president with a portfolio of responsibilities. Normet is a leading manufacturer and supplier of equipment, construction chemicals and rock reinforcement for tunneling and underground mining. It is heavily invested in the processes of sprayed concrete and explosives charging.

In addition to the UCA of SME, Rispin is a member of Professional Engineers Ontario, the Canadian Institute of Mining, Metallurgy and Petroleum, the American Society of Civil Engineers and the American Concrete Institute. He previously served as chair of the Underground Committee of the American Shotcrete Association. He has published papers on explosives, sprayed concrete and equipment. ■

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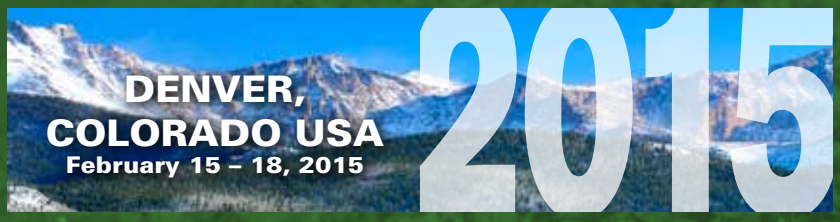
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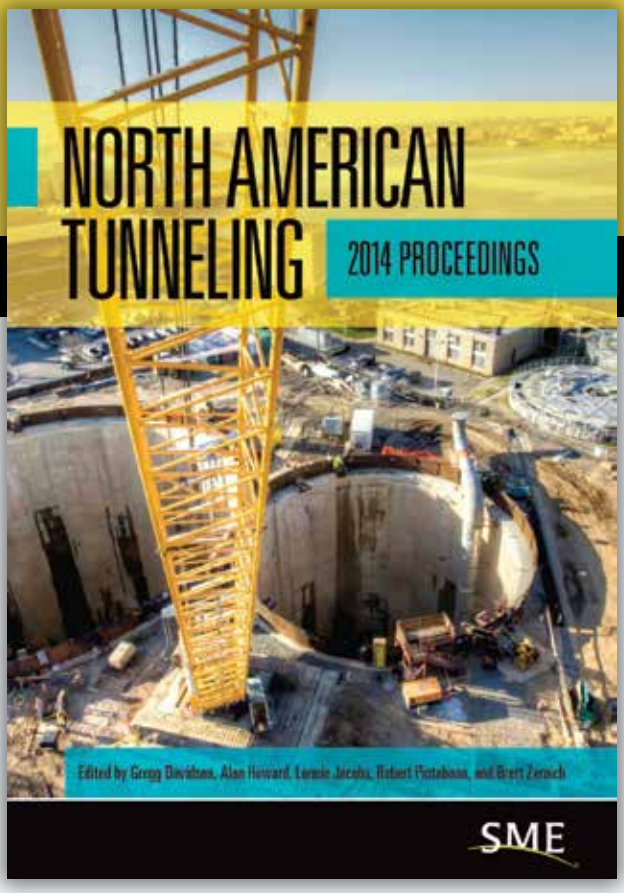
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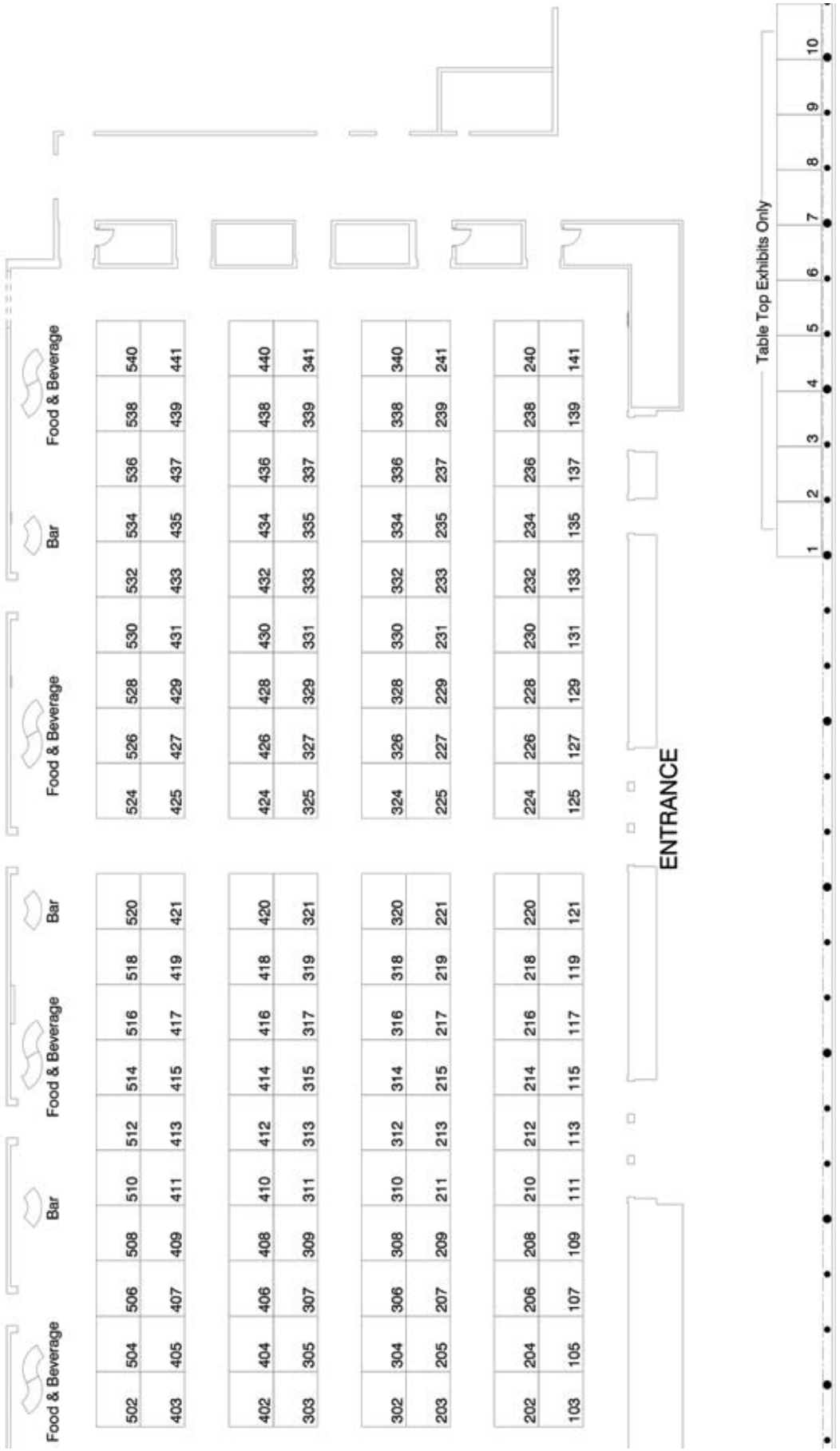
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Booth 302

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AECOM

Booth 336

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Booth 320

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Booth 502

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Fax: (843) 527-2738
Email: salesmkg@agruamerica.com
Website: www.agruamerica.com

AIL Mining

Booth 103

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Products and Services

Ground Improvement Equipment and Services

Main Office

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Stoney Creek, ON L8E 6E7 Canada
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Akkerman

Booth 319

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Main Office

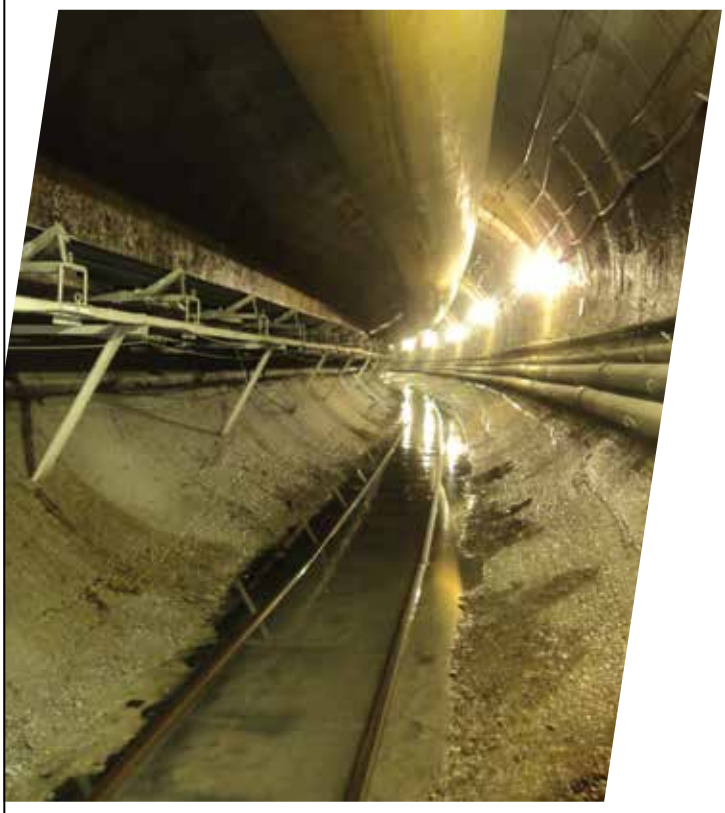
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Alpine Equipment

Booth 420

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Main Office

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Website: www.alpinecutters.com

Amberg Engineering (North America), Inc

Booth 230

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Main Office

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Amberg Technologies AG

Booth 232

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Main Office

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Website: www.amberg.ch/at



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Booth 433

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Booth 4

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Products and Services

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Booth 430

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Booth 325

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Atkins North America
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Atlas Copco CMT-USA
Booth 115

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Booth 137

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Website: www.avantigrout.com

Babendererde Engineers, LLC
Booth 534

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Booth 215

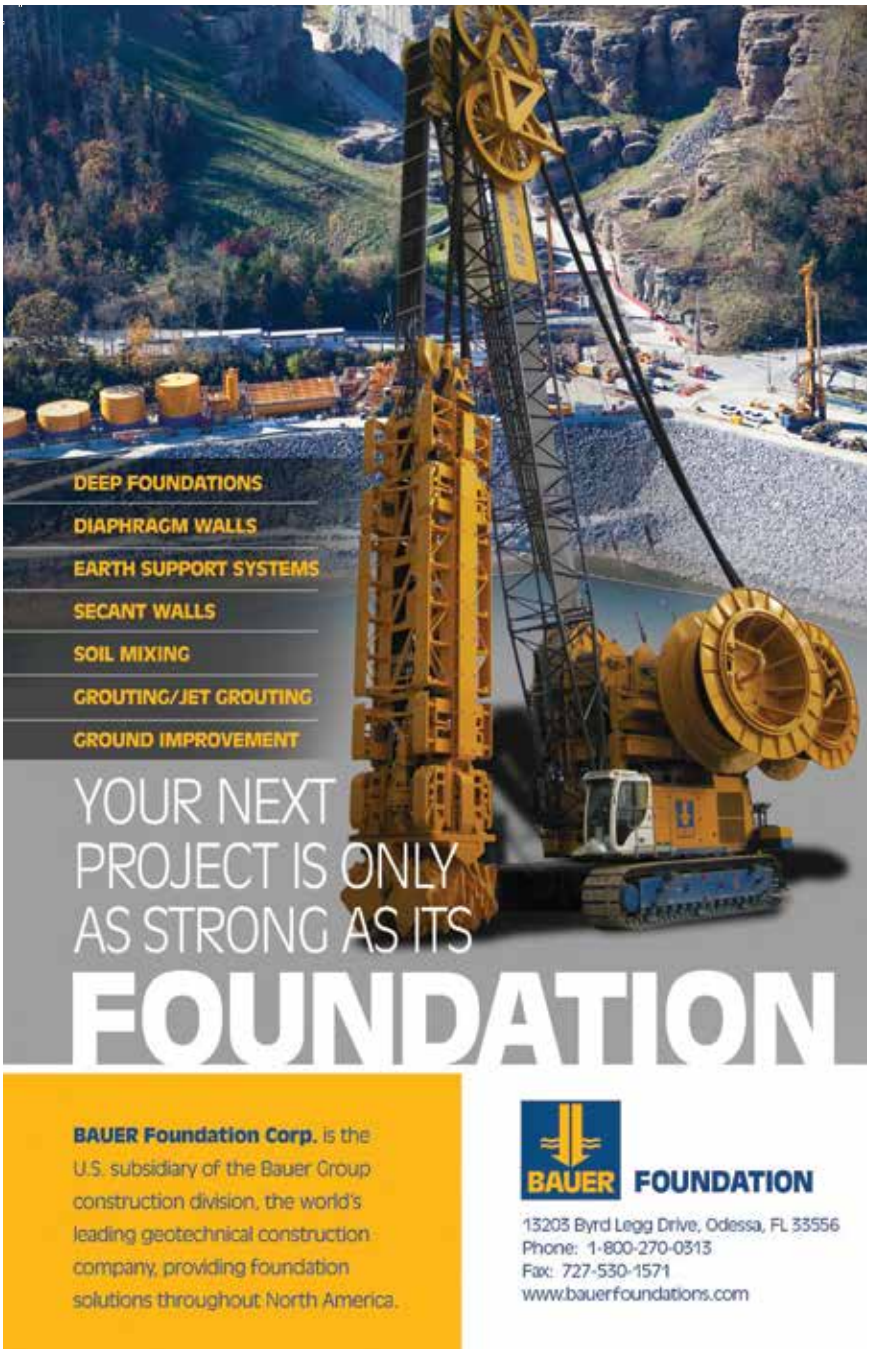
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Main Office

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Houston, TX 77032
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Website: www.baroididp.com



BASF Corporation

Booth 119

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Through its Master Builders Solutions brand, BASF is a leading supplier of underground construction solutions that help tunneling customers to become more successful, even in highly challenging ground conditions. BASF has the largest range of products and services available to meet needs and solve problems in TBM and conventional tunneling, whether in soft ground or hard rock conditions. We offer a full range of MasterRoc® tunneling products such as soil conditioning foams and polymers, anti-clay agents, tail sealants, anti-abrasion agents, dust suppressants, bearing seal greases, EP2 greases and annulus grouts, plus product for sprayed concrete and injection for ground consolidation.

Products and Services

Dust and Fume Control Technology, Lubricants for TBM, Mining Equipment, Precast Concrete Linings, Shotcrete Equipment, Supplies, and Services, Tunnel Lining and Support Materials

Main Office

23700 Chagrin Blvd
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Bauer Foundation Corp

Booth 238

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The Chemical Company

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Website: www.bauerfoundations.com

Bayco Products, Inc
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Becker Mining America
Booth 303

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Phone: (404) 433-6823
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BPS - Bakersfield Pipe & Supply
Booth 105

Products and Services
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Brokk Inc

Booth 113

See our ad on Inside Back Cover

BROKK is the world leader in electrically powered remote controlled demolition machines, which are used extensively in tunneling, shaft sinking, micro-tunneling, scaling, and other underground construction applications. BROKK machines can be equipped with a variety of attachments, such as hydraulic breakers, rock drills, rotary drum cutters, digging buckets, beam manipulators, and shotcrete nozzles. Boasting an impressive power-to-weight ratio, these compact machines can operate effectively in limited access, confined spaces, with zero-emissions. Operators can remain at a safe distance while they maneuever BROKK machines in challenging areas underground.

Products and Services

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Main Office

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Monroe, WA 98272
Phone: (413) 537-5572
Fax: (360) 805-2521
Website: www.brokkinc.com

Brookville Equipment Corp

Booth 528

See our ad on page 14

Brookville is a leading manufacturer of rail-mounted diesel and battery-powered tunneling locomotives and personnel carriers. Featuring planetary final drive gear reducers at each wheel end to divide driveline torque, shock loading for reduced stress and longer service life, and liquid-cooled internal wet disc brakes to extend brake life and provide maximum braking capacity for long, continuous grades, Brookville units are designed for dependability. Optional equipment features include explosion proofing and patented on-board rerailing systems to enhance safety in all work environments. Brookville also manufactures rubber-tired equipment, ideal for steep tunnel grades, inspections, and maintenance for non-tracked projects.

Products and Services

Mining Equipment, Rail Products, Underground Locomotives and Rail Haulage Equipment

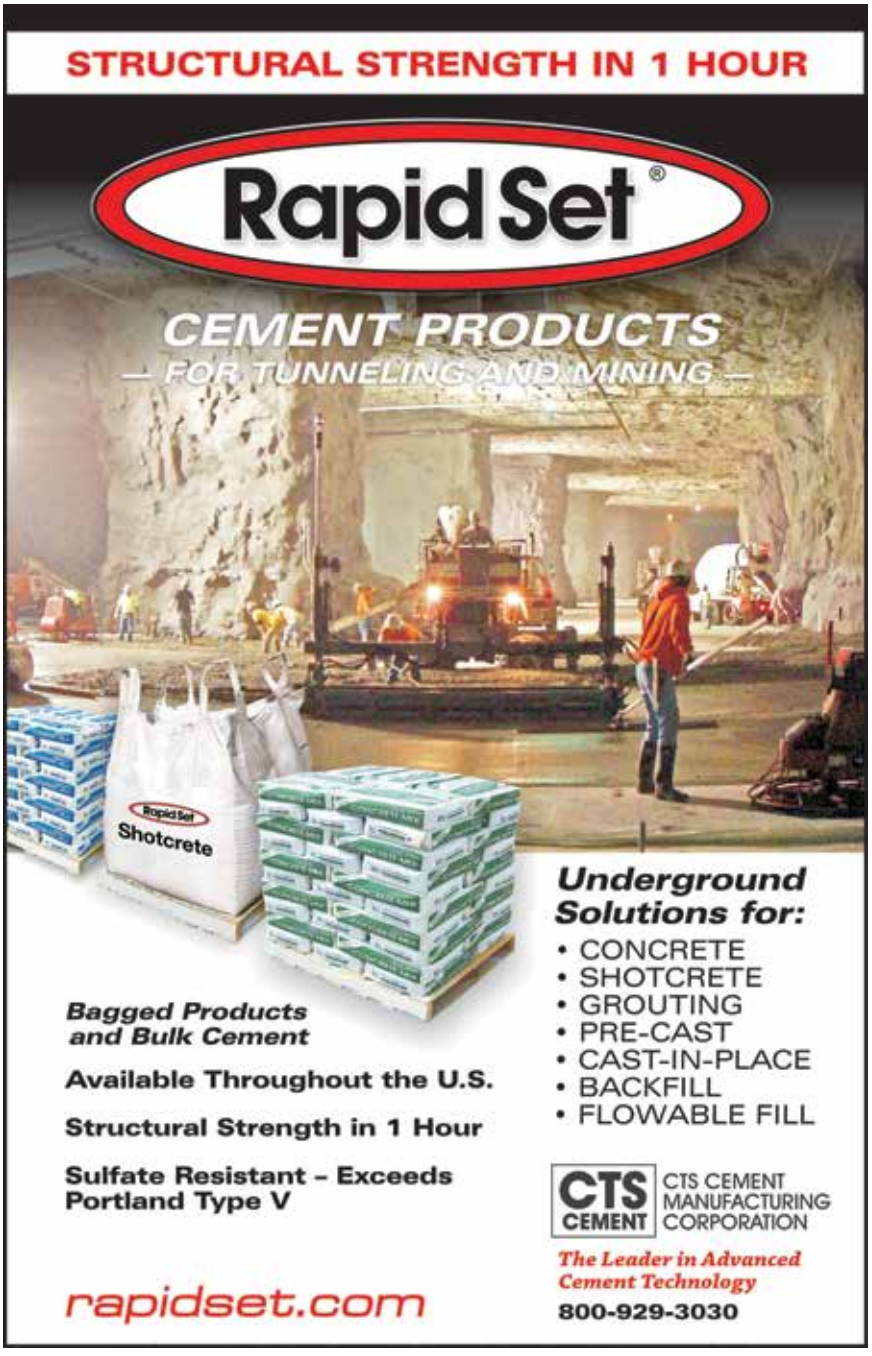


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Brookville, PA 15825
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Fax: (814) 849-2010
Website: www.brookvillecorp.com

c2pm
Booth 206

C2PM is a professional consulting firm specializing in a full spectrum of program management, construction management, and related construction support services for Infrastructure, Tunneling, Transportation, Aviation, Maritime, Federal, Water and Wastewater projects. C2PM pairs proactive management with client-focused attention to solve complex problems. This methodology has enabled the firm to work on large projects including the $1.3B Alaskan Way SR99 Tunnel, the $1.5B Delaware/ Catskill UV Treatment Plant for New York DEP, the BART Submerged Transbay Tube Seismic Retrofit project, as well as the Berth 144-145 ICTF with the Port of Los Angeles.

Products and Services
Construction - Contracting Services, Consulting Engineers, Engineering Design and Services for Tunnels



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Irvine, CA 92618
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Website: www.c2pm.com

Cascade Drilling L.P.
Booth 436

Boart Longyear E&I is a full service provider of drilling services specializing in the application of its Sonic drilling system for tunnel professionals globally. Boart has applied the Sonic system for numerous soft ground tunnel projects globally in support of both design and construction efforts.

Products and Services
Drilling Services and Equipment

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Marietta, OH 45750
Phone: (614) 402-1808
Fax: (740) 350-5003
Website: www.boartlongyear.com

CDM Smith
Booth 510

See our ad on page 15

CDM Smith provides lasting and integrated solutions in water, environment, transportation, energy and facilities to public/private clients worldwide. As a full-service engineering and construction firm, we deliver exceptional client service, quality results and enduring value across the entire project life-cycle.CDM Smith's underground construction staff includes geotechnical, structural, and civil engineers and geologists located across the globe. With a full range of tunnel related services, we provide planning, feasibility and design - both 2D and 3D FEM analyses, construction services, program management, inspection and geotechnical instrumentation monitoring and data interpretation.

Products and Services
Consulting Engineers, Earth Pressure Balance Machines, Engineering Design and Services for Tunnels, Geological, Geotechnical Services and Equipment, Ground Freezing, Rock TBM's

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CETCO
Booth 416

CETCO offers solutions for commercial, industrial and infrastructure construction challenges worldwide. We provide expertise in transforming minerals and polymers into technologies that improve productivity and performance. From technical problem-solving to on-site supervision, CETCO consults with customers to develop long-term solutions.

Products and Services
Grouting Services, Equipment and Materials, Lubricants for TBM, Microtunneling Equipment, Tools, and Supplies, Slurry Services and Machines, Tunnel Lining and Support Materials

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Hoffman Estates, IL 60192
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Email: marketing@cetco.com
Website: www.cetco.com

ChemGrout, Inc
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With more than 50 years of experience, ChemGrout continues to manufacture the worlds largest selection of grouting equipment. ChemGrouts underground series offers exceptional productivity for the contact grouting, water cut-offs, cable stays and rock bolts. Its patented pumps are industry standards offering reliability and durability, along with unique features simplifying clean up and maintenance. Offering many unique and innovative features, ChemGrout has remained the industry leader in underground grouting since 1963.

Products and Services
Grouting Services, Equipment and Materials

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Website: www.chemgrout.com

Condor Earth Technologies, Inc
Booth 304

Condor is a leader in geotechnical/geological evaluation and design of small and medium sized tunnel projects throughout California. With over 50 employees in four California offices, Condor provides a variety of earth and environmental science, engineering, mapping, GIS, materials testing/special inspection, and construction management and monitoring services to private and public sector clients. Condor's experience includes evaluating geological hazards; geotechnical, investigations; slope stability evaluation; cut/cover and tunneling conditions; geotechnical baseline reports; tunnel liner, shaft and portal design; canal and tunnel rehabilitation; tunnel construction management; and materials testing. Condor currently has openings for associate and senior level geologists and engineers.

Products and Services
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Crux Subsurface, Inc
Booth 441

Crux is a leader in geotechnical construction and exploration. With more than 10 years experience in the tunneling industry, the company has provided solutions to some of the most difficult-access and geologically challenging projects in North America. Crux specializes in long range deviation-controlled horizontal core holes, borehole surveying, optical and acoustical televiewer services, high-quality sampling, and instrumentation installation. Pre-excavation stabilization services include dewatering, permeation and compaction grouting, tube arch canopies, and cased horizontal boreholes. Crux provides design-build services and a fleet of custom designed equipment to ensure unique project needs can be met.

Products and Services
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Spokane Valley, WA 99027
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Fax: (509) 892-9408
Website: www.cruxsub.com

CTS Cement Manufacturing Corp
Booth 540

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Rapid Set® cement products are high performance concrete materials used for underground roadway repair for ramps, underground maintenance facilities, and anywhere rutted out sections in mines need attention. Rapid Set products are great for extra high strength and abrasion resistant shotcrete in high traffic areas and in ore shafts. High strength, low shrinkage Rapid Set grout achieves strengths up to 7500 psi (55 MPa) in four hours. Rapid Set® cement products achieve high strength much faster than most any other cement based products in the market. Many installations can be put into service in as soon as one hour.

Products and Services
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Main Office
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Cypress, CA 90630
Phone: (801) 209-0599
Website: www.ctscement.com

Daigh Company, Inc
Booth 313

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Supplier of Da-mite Rock Splitting Mortar, a non-explosive solution to fracture rock and concrete in no-blast conditions. Da-mite is an ideal & effective tool for fracturing mass rock, boulders, trench rock, dimensional stone, tunnels, concrete and reinforced concrete. Easy to use, Da-mite is mixed with water & placed in drilled holes, where it sets and expands to break the rock or concrete. Da-mite has more than enough force to get the job done. No license required. Four grades of Da-mite provide enough versatility to be utilized in drilled hole diameters from under 1, up to 2 3/4.

Products and Services
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Fax: (770) 887-3783
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Website: www.da-mite.com

Datwyler Sealing Technologies Deutschland GmbH
Booth 538

Datwyler, Division Sealing Technologies, is the world leading provider of tunneling gaskets. With the newly acquired Phoenix PDT Profiles business, Datwyler features successful references in more than 450 tunnels on five continents. The company offers many gasket profiles and material options, designed and offered on a project basis, for hydrostatic and/or environmental conditions encountered. Datwyler now manufactures five types of gaskets to meet a wide range of tunnel applications: mono EPDM, hydrophilic, Co-ex Swell/Composite Black Swell and the new anchored gasket. Anchored gaskets are the new generation for segmental tunneling gaskets now being used in the first USA tunnel projects.

Products and Services
Tunnel Lining and Support Materials

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Fax: (201) 930-0050
Website: www.datwyler.com

David R. Klug & Associates, Inc
Booth 220

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David R. Klug & Associates, Inc. provides international and national manufacturer representative services to the underground heavy civil and mine construction industries. The company specializes in the coordination of products, equipment and services for NATM, soft ground, precast segmental and conventional tunnel construction. This includes initial support systems, GFRP bolts and soft-eye structures, flexible membrane waterproofing

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- ChemGrout Grouting Equipment
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Products and Services
Concrete Reinforcement, Precast Concrete Linings, Tunnel Lining and Support Materials

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DeNeef Construction Chemicals, Inc
Booth 228

With over 30 years of experience, DeNeef Construction has built a strong presence as the leading polyurethane grout manufacturer in the world. DeNeefs cutting edge technology and dedicated contractor support team has proven invaluable to its success and the success of its clients. DeNeef will introduce products such as superflex, its new durable flexible acrylate grout with field adjustable set times of 3 seconds to 3 hours. The following will also be displayed: full line of injectable tubes, waterstops, microfine cements, methacrylates, epoxies, polyurethanes, acrylates and more.

Products and Services
Grouting Services, Equipment and Materials

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Fax: (713) 849-3340
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Derrick Equipment Co
Booth 213

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Products and Services
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DFS West
Booth 209

See our ad on this page

Products and Services
Safety Products

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Fax: (775) 623-4279

Dibit Measuring Technique USA, Inc
Booth 309

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Products and Services
Survey Equipment and Lasers



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Website: www.dibit.at

Dr. Sauer & Partners Corp
Booth 235

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Dr. Sauer & Partners has been in practice in the United States for over 25 years, and employs tunnel engineers at main offices located in Washington D.C., London and Salzburg. The firm provides cost effective and innovative tunneling solutions using conventional mining approaches to owners and contractors. Dr. Sauer & Partners is recognized worldwide as one of the leading consultants for design and construction supervision of tunnels and underground structures. The application of innovative design solutions and high quality field supervision has led to the successful completion of numerous transportation and utility tunnels.

Products and Services
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Herndon, VA 20170
Phone: (703) 707-0700
Fax: (703) 707-0703
Email: washington@dr-sauer.com
Website: www.dr-sauer.com

DSI Underground Systems
Booth 217

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DSI Underground Systems Inc. is a world leader in ground support systems for mines and tunnels. DSI manufactures a variety of roof bolts, steel ribs, liner plates, lattice griders & canopy umbrella systems for its customers ground support needs. DSI's Equipment Division represents some of the world's best known products for mining & tunneling, from communications equipment to Pile Top Drills. DSI is proud to represent such companies as Biomarine Tunnel Rescue Equipment, Boart Longyear drilling products, ChemGrout, Condat lubricants, Montabert hydraulic breakers and drills, Hany grouting equipment, Pyott Boone pager phones and AkerSolution Pile Top & Blind Bore Drills.

Products and Services
Grouting Services, Equipment and Materials, Lubricants for TBM, Roadheaders, Safety Products, Tunnel Communication Systems and Equipment, Tunnel Lining and Support Materials

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Louisville, KY 40206
Phone: (276) 698-4738
Fax: (502) 473-0707
Website: www.dsiunderground.com

Elasto Plastic Concrete
Booth 404

See our ad on page 22

Elasto Plastic Concrete is the market leader in development of the highest range of BarChip Macro synthetic fibers designed for the toughest tunneling projects. Elasto Plastic Concrete has supplied over 300 tunnel projects worldwide in both NATM primary and secondary linings as well as in tunnel segmental linings in hybrid fiber/steel and solo fiber segmental designs. BarChip fiber is manufactured to all ASTM standards and is the toughest fiber in the market providing the lowest performance based cost in tunnel linings. BarChip is more durable than steel fiber and is not affected by corrosion or early age embrittlement.

Products and Services
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Euclid Chemical Co
Booth 318

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Products and Services

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Everest Equipment Co

Booth 536

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Products and Services

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Gall Zeidler Consultants

Booth 418

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Products and Services

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Geocomp/ GeoTesting Express

Booth 231

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Products and Services

Consulting Engineers, Engineering Design and Services for Tunnels, Geological, Geotechnical Services and Equipment, Instrumentation Equipment and Services

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Booth 412

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Products and Services

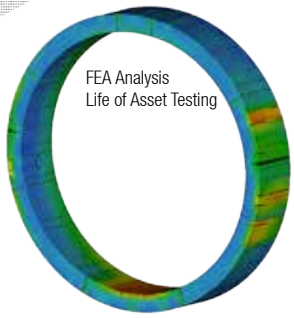
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Booth 437

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Products and Services
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Grindex Pumps
Booth 241

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A complete line of highly efficient and reliable submersible pumps designed for heavy-duty drainage/sludge applications. Range from 0.6 to 140 HP. Solids handling capability of up to 3.2 in., capacities of up to 750 ft. and 5,100 GPM. On construction sites, in mines and various industrial applications, Grindex submersible pumps are constantly being put to the test in some of the most demanding applications imaginable. Air cooling valves permit pumps to run dry without damage. With SMART motor protection, Grindex Pumps will not run backwards, will not single phase, will not overheat.

Products and Services
Pumps and Pumping Equipment

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Halfen Anchoring Systems
Booth 421

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Products and Services
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Website: www.halfenusa.com

Hatch Mott MacDonald
Booth 202

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Hatch Mott MacDonald provides tunnel design and engineering solutions for rail and transit, road, water/wastewater conveyance, CSO storage, and cable and communications. With a reputation for technical excellence, Hatch Mott

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Website: www.hatchmott.com

HAYWARD BAKER
Geotechnical Construction
KELLER

Hayward Baker Inc

Booth 205

See our ad on Outside Back Cover

Hayward Baker Inc. is North America's leader in geotechnical construction, and is ranked #1 in the field by ENR. Hundreds of tunneling projects! Jet grouting and soil mixing stabilize soft soils to allow TBMs to safely bore through them. Jet grouting and soil mixing create tangent or secant pile shafts for tunnel access. Jet, chemical, and cement grouting stabilize soils around break-ins and break-outs and control groundwater. Anchors, shotcrete, and grouting techniques stabilize tunnel liners. Compaction grouting densifies loose soil under tunnel alignments, and helps relevel TBMs. Fracture, chemical, and compaction grouting control settlement of overlying structures during tunnel boring.

Products and Services

Construction - Contracting Services, Drilling Services and Equipment, Geological, Geotechnical Services and Equipment, Ground Improvement Equipment and Services, Jet Grouting Equipment and Services, Shotcrete Equipment, Supplies, and Services

Main Office

7550 Teague Rd, Ste 300
Hanover, MD 21076
Phone: (410) 551-8200
Fax: (410) 799-3786
Email: info@haywardbaker.com
Website: www.haywardbaker.com

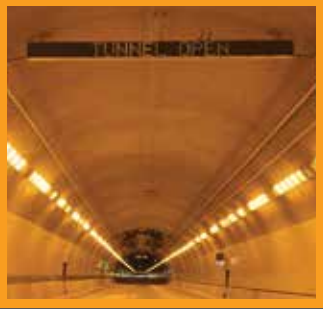
Heintzmann Corp

Booth 328

See our ad on page 27

The Heintzmann Group, which has been in business approximately 165 years, manufactures support systems in the tunneling and mining industries. In the last decade, the company has greatly expanded its line of products, as well as regions of service. Heintzmann currently has

A World Leader in Tunnel Engineering, Geotechnics, and Construction Management

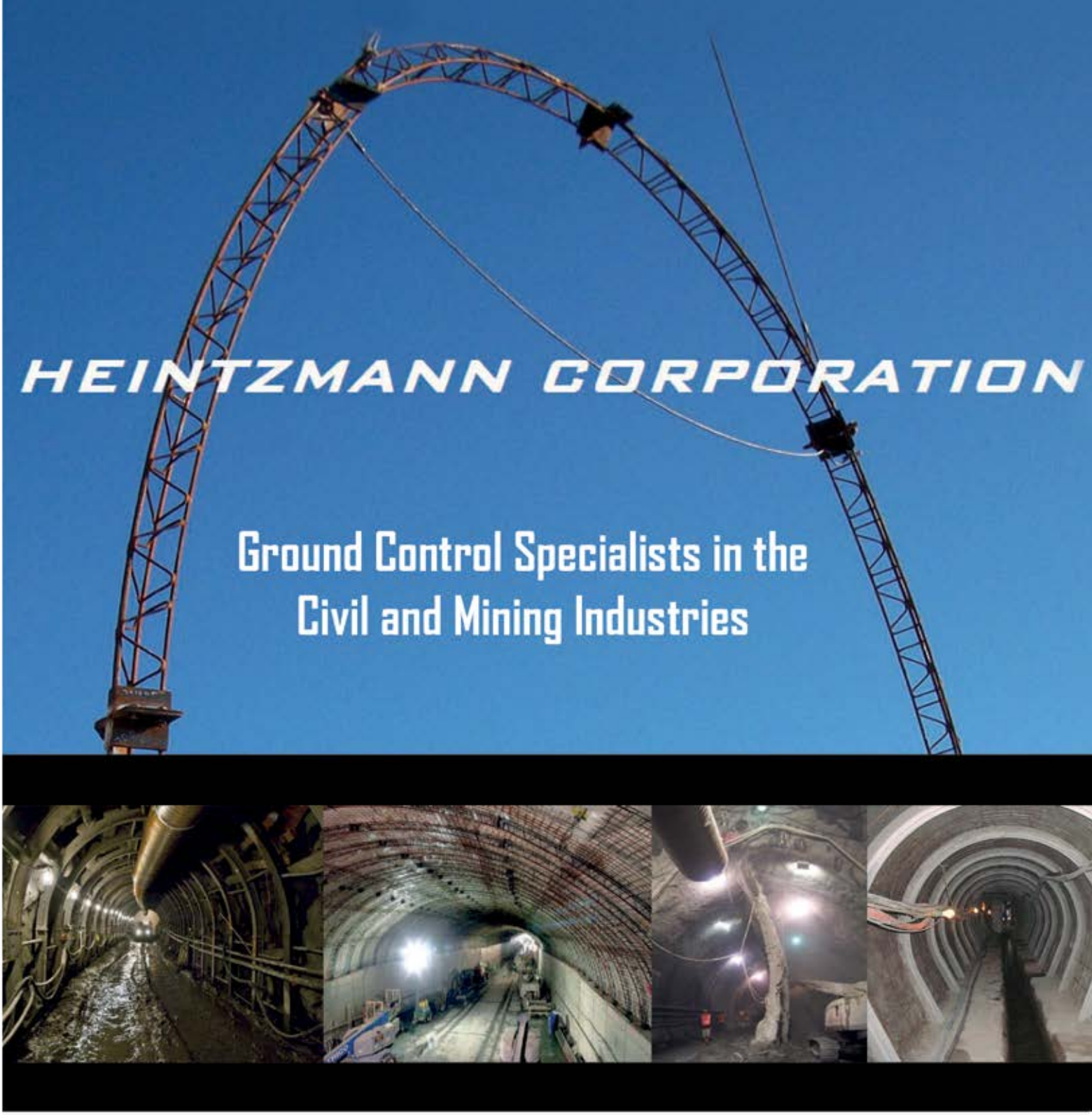




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- People Mover, Dulles Airport
- East Side Access
- No. 7 Flushing Line
- Port of Miami Tunnel
- Devil's Slide Tunnels
- TVA Hydropower
- Beacon Hill Station, Seattle
- London CrossRail
- Caldecott 4th Bore
- Santiago Metro
- Singapore DTL 2
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offices located in Virginia, West Virginia, Alabama, Colorado, and Illinois. Its range of products and services include but are not limited to standing supports, pumpable roof support, arches, square sets, pre-stressing devices, heat treated beams, polyurethane grout injection, shaft rings, lattice girders, two flange liner plates and four flange liner plates.

Products and Services
Concrete Reinforcement, Engineering Design and Services for Tunnels, Ground Improvement Equipment and Services, Tunnel Lining and Support Materials

Main Office
147 Champion St
Cedar Bluff, VA 24609
Phone: (276) 964-7413
Fax: (276) 963-9389
Website: www.heintzmann.com

Helix Steel
Booth 312

Helix Steel is the manufacturer of Helix Micro-Rebar the only proactive concrete reinforcement in the world. Helix Micro-Rebar, lowers the tensile response of the modulus of elasticity in plain concrete increasing its strain capacity, ductility and flexibility. The performance efficiency of Helix allows use of dosages 2 to 3 times lower than hooked steel fibers. Since Helix Micro-Rebar has a stable tensile response, its design method is based on conventional rebar design and therefore is easily understood, used and implemented by structural engineers worldwide. Due to the lower dosages and design method, Helix is perfect for the underground tunneling world.

Products and Services
Concrete Reinforcement

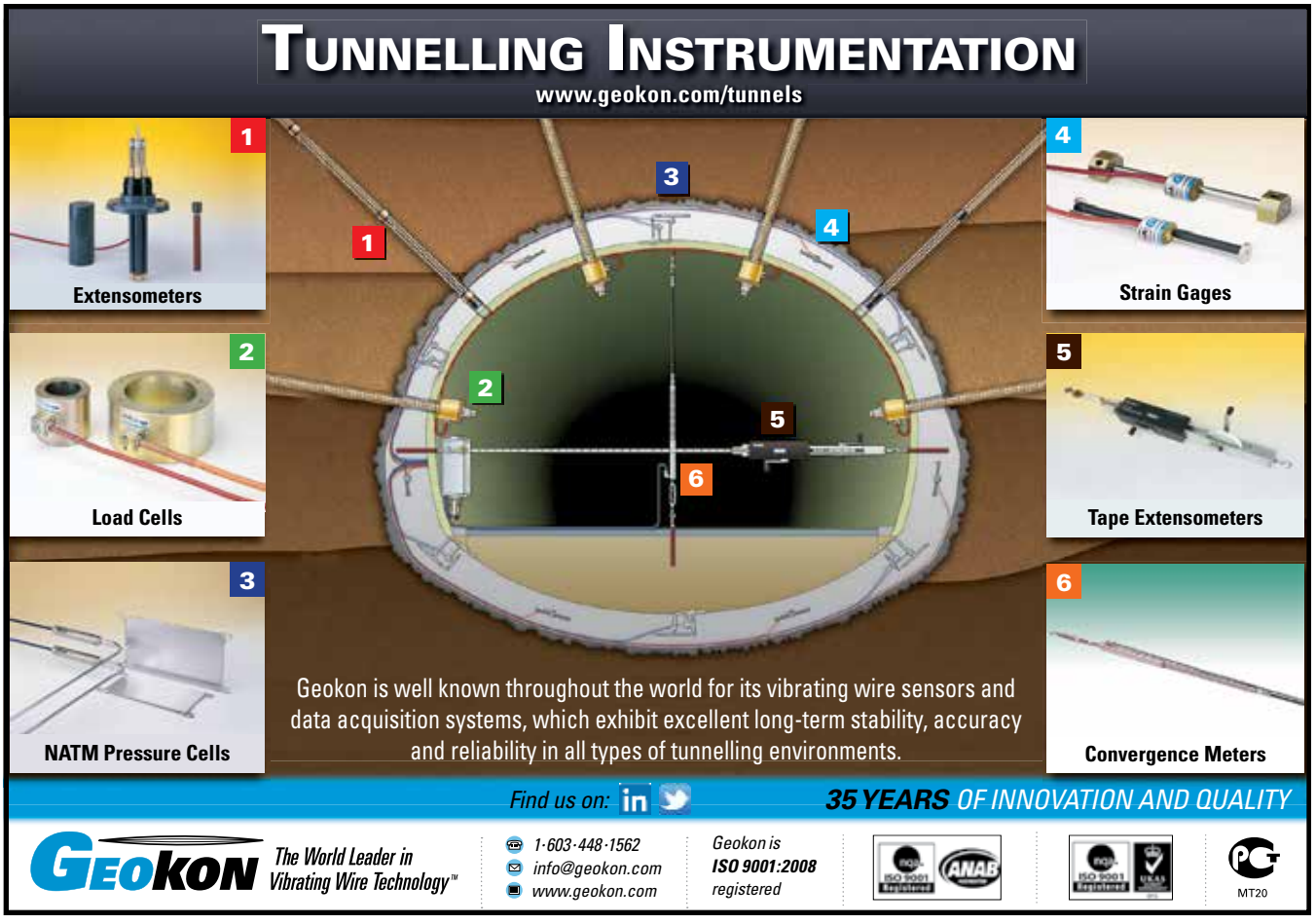
Main Office
300 N Fifth Ave, Ste 130
Ann Arbor, MI 48104
Phone: (734) 322-2114
Fax: (734) 786-1633
Website: www.helixsteel.com

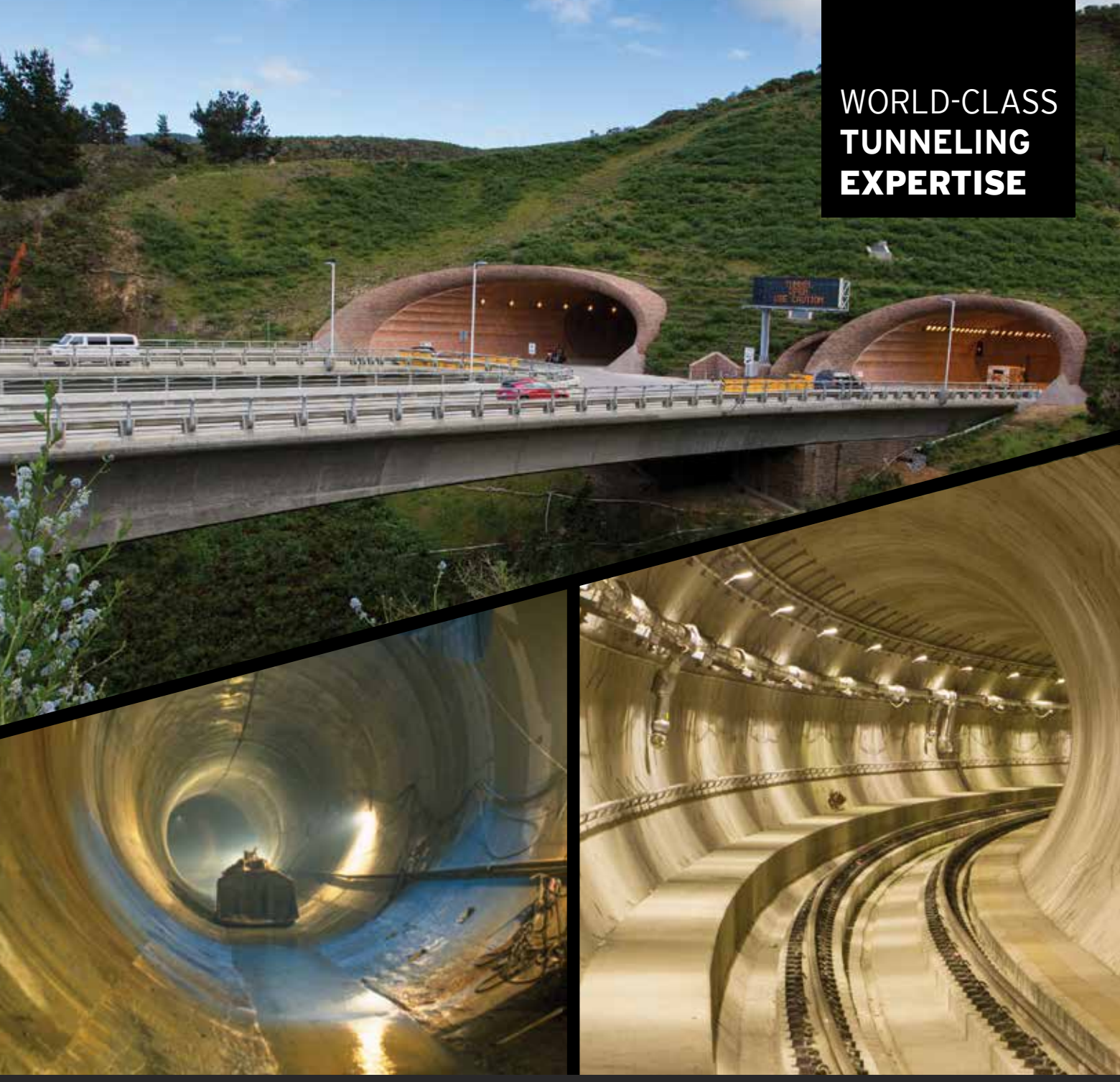
Herrenknecht Tunnelling Systems USA, Inc
Booth 125

Herrenknecht AG is a technology and market leader in mechanized tunnelling for all ground conditions and all diameters from 0.10 to 19 meters. Its product range includes tailor-made machines for traffic and transport tunnels as well as supply and disposal tunnels. Under the umbrella of the Herrenknecht Group, a team of innovative specialists has been formed to provide upon request integrated solutions in the area of tunnel construction with project-specific equipment and service packages. The company also produces state-of-the-art deep drilling rigs that drill down to depths of 8,000 meters and plants for the exploration of shallow geothermal energy.

Products and Services
Earth Pressure Balance Machines, Microtunneling Equipment, Tools, and Supplies, Rock TBM's, Shaft Drilling and Raiseboring Equipment, Soft Ground Shields, Tunnel Boring Equipment

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Sumner, WA 98390
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Senior Vice President
Chair of Tunnel Services
nmmunfah@hntb.com

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HIC Fibers, Inc

Booth 333

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HIC Fibers, Inc. is selling direct in North and South America. HIC Fibers has opened offices in Los Angeles for North America, and Lima, Peru, for Central and South America. This marks the first time that HIC Corp., based in Korea, has opened offices with the intention of selling direct to the end user in lieu of selling strictly through distributors. HIC Fibers has a full line of products including steel and synthetic fibers, rock bolts and anchors, and products for shoring and leveling.

Products and Services

Concrete Reinforcement, Precast Concrete Linings, Tunnel Lining and Support Materials

Main Office

4801 Wilshire Blvd, Ste 305
Los Angeles, CA 90010
Phone: (323) 935-4500
Fax: (323) 935-4501
Email: hicfibers@hicfibers.com
Website: www.hicfibers.com

HNTB Corporation

Booth 224

See our ad on page 29

With 3800 professionals, HNTB is a leader in providing solutions to infrastructure problems nationwide. The firm has a long history in design and engineering services for tunnels and underground construction. HNTB has completed award-winning projects on some of the countrys most complex projects, including highway, transit, rail, aviation and water resources. Recently, HNTB was named Tunneling Advisor/Program Manager of the Year in the 2012 New Civil Engineer International Tunneling Awards for the Devils Slide Tunnel project. HNTB's experts have the insight and knowledge to provide innovative solutions to tunneling challenges, from small diameter excavations to designing the Alaskan Way Tunnel.

Products and Services

Consulting Engineers, Consulting Environmental, Engineering Design and Services for Tunnels

Main Office

5 Penn Plaza
New York, NY 10001
Phone: (212) 594-9717
Website: www.hntb.com

ILF Consultants, Inc

Booth 311

See our ad on page 34

The ILF Group is a 100% private owned consulting firm with more than 40 years of experience. ILF has a permanent staff of over 1,800 employees in more than 30 offices worldwide. The four core areas of ILF's expertise include oil and gas, energy, water and environment, and civil engineering and infrastructure. ILF's underground engineering experience includes: railway, roads, Metro, tunnels, shafts, caverns, mining, and tunnel ventilation systems. The company's particular strength is in its ability to develop and execute complex engineering projects which require overall design and project management services. ILF is your ultimate partner in Underground Engineering.

Products and Services

Consulting Engineers, Engineering Design and Services for Tunnels

Main Office

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Fairfax, VA 22030
Phone: (703) 383-1280
Fax: (703) 383-1281
Email: info.usa@ilf.com
Website: www.ilf.com

Itasca Consulting Group, Inc

Booth 330

Itasca is an international geotechnical consulting company and software developer for the geomechanics, hydrogeologic, and microseismics communities. Itasca has a background of practical engineering and field experience paired with unparalleled knowledge of state-of-the-art numerical modeling and analysis techniques, and the validation of these techniques using field monitoring. Itascas software products are among the most widely used, widely respected tools of their kind. Consulting and research activities focus on the analysis of the performance of groundwater, and rock and soil masses, and the engineered structures that are dependent on their behavior, in the mining, civil, and energy industries.

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Fax: (612) 371-4717
Website: www.itascaconsulting.com

Jacobs Associates
Booth 229

See our ad on page 36

Jacobs Associates provides practical, cost-effective, and innovative solutions for difficult underground projects and excels in the water, wastewater, and transportation sectors. With an emphasis on tunnels and shafts, Jacobs Associates offers a full range of design and construction management capabilities. It also offers the broader heavy civil construction industry a robust package of claims and dispute resolution services. Jacobs Associates is an award-winning firm with 15 offices in the United States, Australia, New Zealand, and Canada.

Products and Services
Construction - Contracting Services, Consulting Engineers, Engineering Design and Services for Tunnels, Geological, Geotechnical Services and Equipment, Tunnel Boring Equipment, Underground Excavation Services and Equipment

Main Office
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San Francisco, CA 94105
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Fax: (415) 956-8502
Email: info@jacobssf.com
Website: www.jacobssf.com

Jennmar Corp
Booth 508

See our ad on page 33

Jennmar is a multi-national, family owned company thats leading the way in ground control technology for the mining and tunneling industry. Jennmar is producing and distributing new products, Expanbol/Python, Arch Support Systems, and Tunnel Liner Plates. Jennmar along with Keystone Mining Services can tailor make Arch Systems for most applications offering cutting edge steel, reliable moment connection design, computerized steel manufacture equipment, complete accessories, optimal design per engineering requirements, and technical support. The goal of Keystone Mining Services and Jennmar is to utilize existing and new products and advanced ground control engineering to improve mine safety and productivity.

Products and Services
Consulting Engineers, Engineering Design and Services for Tunnels, Mining Equipment, Tunnel Lining and Support Materials

Main Office
258 Kappa Dr
Pittsburgh, PA 15238
Phone: (412) 963-5340
Fax: (412) 963-7179
Website: www.jennmar.com

Kenall Lighting
Booth 409

See our ad on page 35

Lighting systems for tunnel applications must endure some of the most challenging physical and environmental conditions, therefore, it is critical that they be built to certified performance standards. Kenall has applied its 50 years of designing, developing, testing, and manufacturing luminaires to meet, and often exceed, the lighting standards and requirements for the Tunnel industry. Fixtures for tunnel applications must not only be designed, engineered and built to address application specific challenges, plus, it is critical to have the manufacturer's support throughout the entire process. Look to Kenall Lighting to solve the challenges for your next lighting project.

Products and Services
Lighting Systems

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Kiewit Infrastructure Co

Booth 307

See our ad on page 37

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Phone: (402) 231-4251
Fax: (402) 346-8610
Website: www.kiewit.com

King Shotcrete

Booth 210

See our ad on page 39

King Shotcrete is a leading manufacturer and supplier of pre-packaged shotcrete, concrete, grout, repair mortar and other cementitious products for North American and International, construction and mining markets. King provides shotcrete material, mixing and placing equipment, along with industry-leading technical services, to support your complete shotcrete operation. To learn more about our products for mining, tunnelling, concrete construction and concrete rehabilitation projects, visit www.kingshotcrete.com.

Products and Services

Concrete Mixing and Transportation Equipment, Concrete Reinforcement, Grouting Services, Equipment and Materials, Mining Equipment, Pumps and Pumping Equipment, Shotcrete Equipment, Supplies, and Services

Main Office

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Burlington, ON L7N 3N2 Canada
Phone: (905) 639-2993
Fax: (905) 333-3730
Email: kingshotcrete@kpmindustries.com
Website: www.kingshotcrete.com

Laborers & Tunnel Contractors Training Trust

Booth 310

Laborers & Tunnel Contractors Training Trust Fund is a joint labor-management training trust fund, formed by a partnership of the Laborers' International Union of North America (LIUNA),Tunnel Contractors and the SME. It provides comprehensive education and training programs to individuals and organizations. The Laborers & Tunnel Contractors Training Trust Fund and the University of Arizona have teamed up to provide this 80-hour course held at the San Xavier Mine. With three working levels, the mine has proven to be an ideal location for underground instruction. Training is available to participants who are willing to work in this field after training.

Products and Services

Educational

Main Office

4201 E Bonanza Rd
Las Vegas, NV 89110
Phone: (702) 334-4031
Fax: (702) 452-9435
Email: merike@training872.com
Website: HardRockTunnel.com

Lachel & Associates, Inc

Booth 514

See our ad on page 38

Lachel & Associates (Lachel), a Schnabel Engineering company, specializes in design and construction management services for tunneling and other heavy civil construction projects in the areas of transportation, water and wastewater infrastructure, and hydroelectric power. We combine our expertise in the design and construction of underground structures with an understanding of nuances and interrelationship of geology, hydrogeology, and geotechnics on underground projects. From inception, through design, risk assessment, estimating, construction, and operations, we provide time-critical answers to difficult questions that make certain the project comes in on time and within budget.

Products and Services

Consulting Engineers, Engineering Design and Services for Tunnels, Geological, Geotechnical Services and Equipment

Main Office

240 Cedar Knolls Rd, Ste 101
Cedar Knolls, NJ 22030
Phone: (973) 734-0200
Fax: (571) 612-5695
Website: www.lachel.com

Layne Geo

Booth 109

Layne GEO is the geotechnical construction division of Layne Christensen Company, providing design-build capabilities and innovative solutions within the fields of ground improvement, deep foundations, earth retention, and customized equipment design and fabrication. Its services are geared toward soil stabilization and subterranean structural support during the construction or rehabilitation of dams/levees, tunnels, shafts, mines, water lines, subways, buildings, highways and marine facilities. Product lines include jet grouting, diaphragm and slurry cutoff walls, cement and chemical grouting, drilled piles, vibratory ground improvement/stone columns and ground anchors. Layne Geo has extensive experience in successful completion of complex, schedule-driven major underground construction projects.

Products and Services

Drilling Services and Equipment, Ground Improvement Equipment and Services, Grouting Services, Equipment and Materials, Jet Grouting Equipment and Services, Shaft Drilling and Raiseboring Equipment, Slurry Services and Machines





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Leister Technologies, LLC
Booth 411

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Booth 225

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Website: www.linepower.com

Luff Industries
Booth 414

Luff Industries manufactures quality conveyor components, including idlers with patented polymer end caps and pulleys with an industry leading rim thickness to an international market. Using Luff components, companies have been increasing the performance of their conveyor systems for 35 years. Recognized for innovative products, quick turnaround times and industry leading warranty, Luff products can be found in a variety of heavy industrial material handling applications. These industries include aggregate, mining, forestry, original equipment manufacturers, construction and recycling. Luff manufactures one of the most complete product lines due to these different application requirements.

Products and Services
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— *Joseph Restelli, General Manager Heavy & Highway Division, Sargent Electric Company*

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Maccaferri Inc

Booth 339

See our ad on page 40

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Products and Services

Concrete Reinforcement, Consulting Engineers, Educational, Precast Concrete Linings, Shotcrete Equipment, Supplies, and Services, Tunnel Lining and Support Materials

Main Office

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Williamsport, MD 21795
Phone: (800) 638-7744
Fax: (301) 223-4590
Email: info@maccaferri-usa.com
Website: www.maccaferri-usa.com



Malcolm Drilling Co Inc

Booth 211

See our ad on page 41

Malcolm Drilling Company, Inc. has for 5 decades been an innovator and leader in the deep foundation industry. Malcolm's list of core services as it relates to tunneling and geotechnical construction includes drilled shafts, support of excavation systems, cutoff and secant pile walls, grouting techniques, various soil mixing methods and dewatering. These combined services have routinely been applied on numerous complex tunneling projects throughout North America. The company's engineering experience facilitates design/build efficiency and allows for timely collaboration with owners and contractors. This delivery system optimizes cost savings while offering inherent scheduling advantages.

Products and Services

Drilling Services and Equipment, Ground Improvement Equipment and Services, Grouting Services, Equipment and Materials, Jet Grouting Equipment and Services, Non-Explosive Mechanical Excavation, Shaft Drilling and Raiseboring Equipment

Main Office

92 Natoma St
San Francisco, CA 94105
Phone: (415) 901-4400
Fax: (415) 901-4421
Website: www.malcolmdrilling.com

Mapei Corp

Booth 208

MAPEIs Underground Tunneling Technology (UTT) category offers a complete line of products and associated technologies for use in and on underground construction projects, including shotcrete accelerators and admixtures for concrete, as well as products for injection and consolidation, mechanized tunneling (TBM), engineering and soil stabilization, coating and protection, maintenance, repair and waterproofing.

Products and Services

Shotcrete Equipment, Supplies, and Services, Soil Conditioning Equipment and Materials, Underground Excavation Services and Equipment

Main Office

1144 E Newport Center Dr
Deerfield Beach, FL 33442
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Fax: (954) 246-8801
Website: www.mapei.com

McDowell Equipment Ltd

Booth 530

Since 1968 McDowell Equipment has continued to provide the mining sector with heavy equipment. With more than 100 employees and over 75,000 square feet of shop space, McDowell Equipment provides new, rebuilt/reconditioned or good used equipment for sale and or rental. McDowell's parts division offers clients the ability to exchange components for rebuilt or new ones saving valuable down time. The company's world wide dealer network helps reduce delivery times as

Kiewit



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well. McDowell Equipment continues to search for surplus equipment and parts around the world and even trade-ins are welcome.

Products and Services

Microtunneling Equipment, Tools, and Supplies, Mining Equipment, Shotcrete Equipment, Supplies, and Services, Tunnel Haulage Systems, Underground Excavation Services and Equipment, Underground Locomotives and Rail Haulage Equipment

Main Office

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Sudbury, ON P3B 4J8 Canada
Phone: (705) 566-8190
Fax: (705) 566-6680
Email: sales@bmcdowell.com
Website: www.bmcdowell.com

MCT Murer Consult GmbH

Booth 338

Main Office

166 Mason St, #2
Greenwich, CT 06830-6611
Phone: (203) 554-0705
Website: www.mct-murer.ch

Measurand Inc

Booth 415

Products and Services

Geological, Geotechnical Services and Equipment, Instrumentation Equipment and Services

Main Office

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Fax: (506) 462-9095
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Messinger Bearings

Booth 432

See our ad on page 43

Surpassing 100 years, Messinger Bearings is one of an elite few companies in the world capable of producing large (up to 25 feet in diameter), custom-designed bearings in limited quantities for tunnel boring machines (TBMs). In fact, Messinger focuses on manufacturing new and expert repairing of large custom



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Products and Services
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MineARC Systems
Booth 428

Established in 1999, MineARC Systems is the global leader in the manufacture and supply of emergency refuge systems to the underground mining, tunneling and chemical processing industries. Emergency refuge is integral to an operations wider emergency response plan (ERP). Fires, explosions, rock-falls and the release of smoke and toxic gases occur all too frequently despite high levels of planning and precautions. In these types of emergencies, when evacuation is no longer safe or practical, emergency refuge provides a secure go-to area for personnel to gather and await extraction. MineARC refuges have been used to save lives around the world.

Products and Services
Air Locks and Bulkheads, Mining Equipment, Safety Products, Tunnel Boring Equipment

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Dallas, TX 75236
Phone: (214) 337-5100
Fax: (214) 337-5103
Website: www.minearc.com

Mining Equipment Ltd
Booth 315

See our ad on page 42

Mining Equipment has been supplying the mining and tunneling industries with quality rebuilt underground equipment for more than 30 years. The business has grown to encompass new ventilation equipment, Jetair fans, and new rolling stock, C.S. Card and Moran Engineering. Mining Equipment, Jetair and Mine Hoists International are currently doing business in North and South America, Australia, Asia, Africa and Europe.

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Moretrench
Booth 326

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Above Left: **Vargas Access Shaft** New Irvington Tunnel, Fremont, CA
Left: **Mega-Jet Grouting** Seattle WA. Main: **Port of Miami Tunnel** Miami, FL

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Naylor Pipe Co
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Booth 141

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Nicholson Construction Co
Booth 133

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North American Tunneling Journal/ Tunnelling Journal
Booth 10

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Booth 403

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Booth 329

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Booth 526

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Booth 417

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Booth 431

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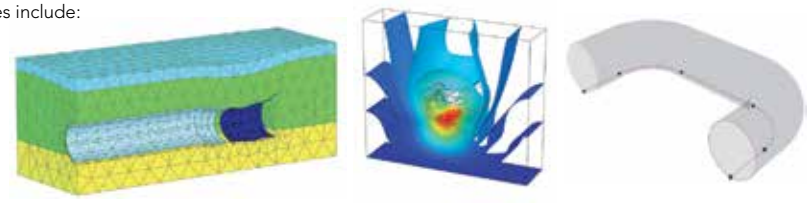
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Booth 216

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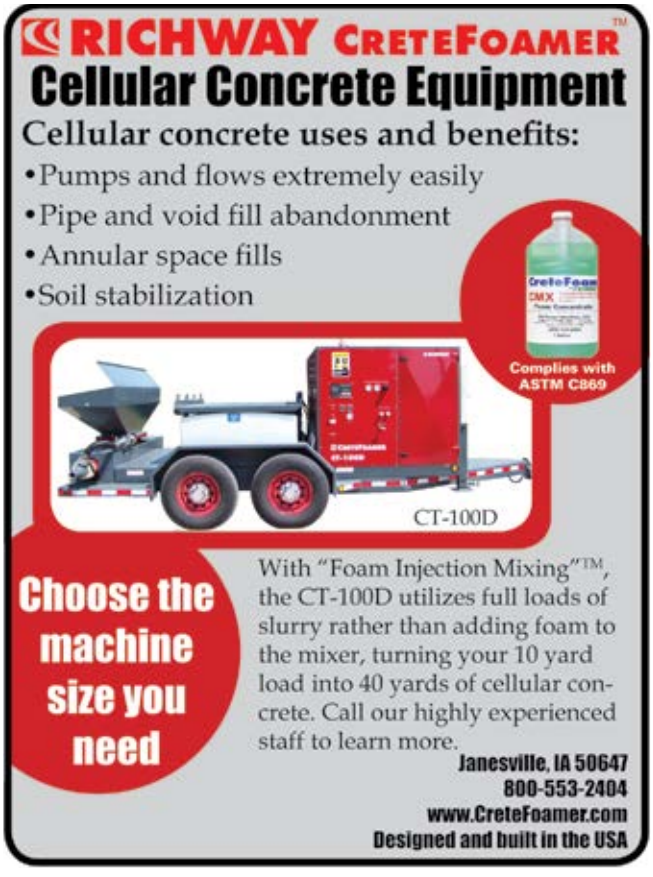
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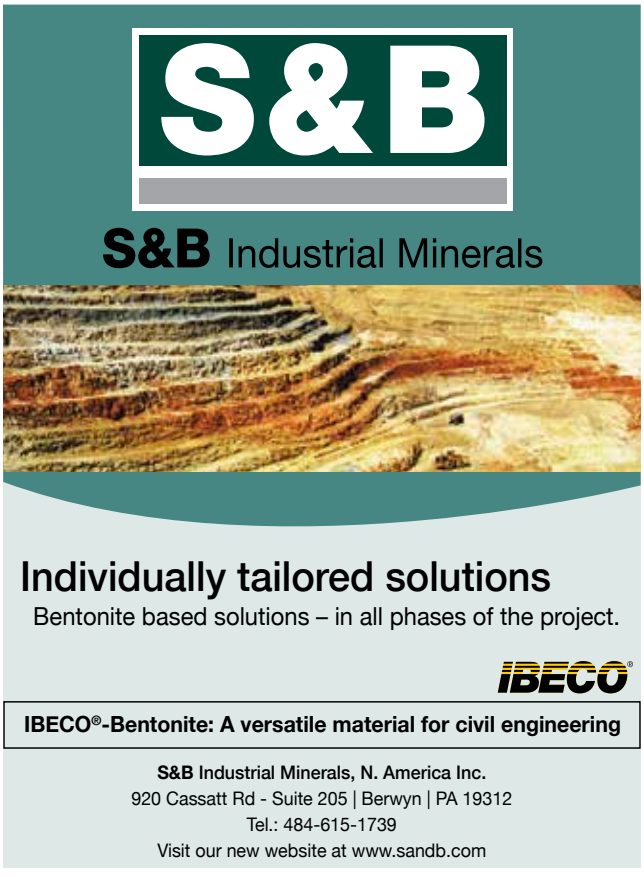
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S&B Industrial Minerals North America Inc
Booth 139

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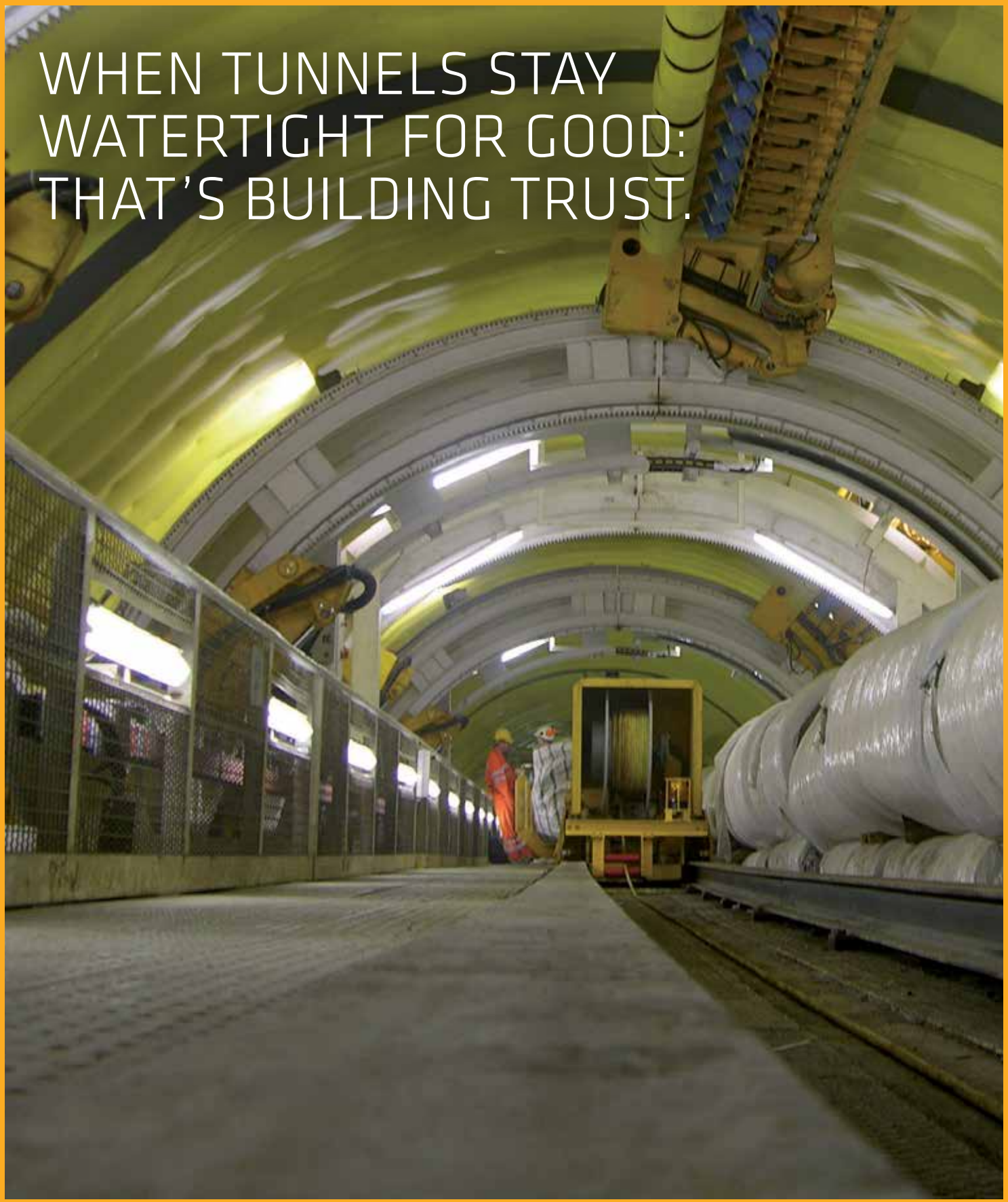
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Booth 516

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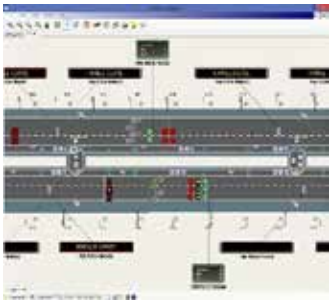
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BUILDING TRUST

SIDERA
Intelligent Traffic System

SIDERA ITS is SICE's versatile and scalable integrated traffic management solution Applicable to a wide range of mission critical ITS projects including all types of roadways, bridges, tunnels or a combination of all.

SIDERA's user-friendly, intuitive and flexible interface allows transportation center operators to effectively manage the network by seamlessly controlling roadside equipment, emergencies, planned and unplanned events, etc.







Key features of the system include:

Real-time monitoring and incident management

Extensive data and reports capability

GIS based GUI that improves multi-asset control and monitoring

Fault-tolerant design including data replication and automatic fail-over

Advanced incident response suite including real-time decision-support to the operator and configuration of response plans

Control centre to control centre (C2C) integration

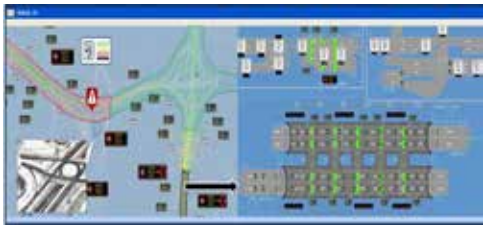
Cross-platform application, cost effective and compliant with the most important industry PLC vendors

Asset management capabilities resulting in improved whole-of-life

State-of-the-art maintenance features i.e. alarm paging or maintenance crew vehicle positioning control

Seamless integration with other systems (tolling, intersection control, etc)

Support for integration with commercially available RDBMS, PLC vendors, and reporting platforms and 24x7 worldwide support



www.sice.com

Main Office

300 Technology Ct
Smyrna, GA 30082
Phone: (404) 589-2823
Fax: (404) 589-2923
Website: www.construction.sandvik.com

Schauenburg Flexadux Corp

Booth 506

See our ad on page 54

Schauenburg offers a complete line of ventilation products and ventilation design assistance for the mining and tunneling industry. Its products include forced air ventilation ducting, cassette systems for tunneling, flexible wire reinforced suction ducting, high pressure couplings, phenolic fiberglass ducting, inflatable stoppings, fans and dust collectors (wet or dry) as well as all fittings and adapters required to complete your ventilation system. In addition, Schauenburg carries gas detection radio cap lamps, brattice line curtains, tarps, brattice cable hangers, powder bags and cushions. All of its ventilation products are MSHA approved for underground use.

Products and Services

Dust and Fume Control Technology, Safety Products, Ventilation Systems, Materials and Equipment

Main Office

2233 Sanford Dr
Grand Junction, CO 81505
Phone: (970) 245-9400
Fax: (970) 245-9402
Email:
Website: www.schauenburg-us.com

Schnabel Foundation Co

Booth 520

Schnabel Foundation Company is a specialty geotechnical contractor that has been designing and constructing earth retention and deep foundation projects for over 50 years. Schnabel has a wide range of design and construction methods to provide the tunneling industry with the best possible circular access shaft or water cutoff retention system. These methods include secant piles, jet grouting and soil mixing, along with more conventional earth support systems and micropile foundations. Schnabel's numerous offices throughout the United States and in-house design capabilities allow a tailored fit system for project specific needs.

Products and Services

Construction - Contracting Services, Drilling Services and Equipment, Ground Improvement Equipment and Services, Grouting Services,

STRATA
WORLDWIDE



EMERGENCY REFUGE CHAMBERS *for* TUNNELING.

Strata Worldwide will be at the **North American Tunneling Conference** from June 22-25, 2014 in Los Angeles, California.

Strata Worldwide, a global leader in mine refuge chambers, now offers state-of-the-art emergency chambers for tunneling applications. Tunneling chambers are custom built using individual customer specifications and can be attached directly to Tunnel Boring Machines (TBMs), mounted on rails, or strategically positioned within the tunnel. Strata emergency refuge chambers are made to always be where you need them, when you need them.

STRATAWORLDWIDE.COM

INFO@STRATAPRODUCTS.COM | 1.800.691.6601

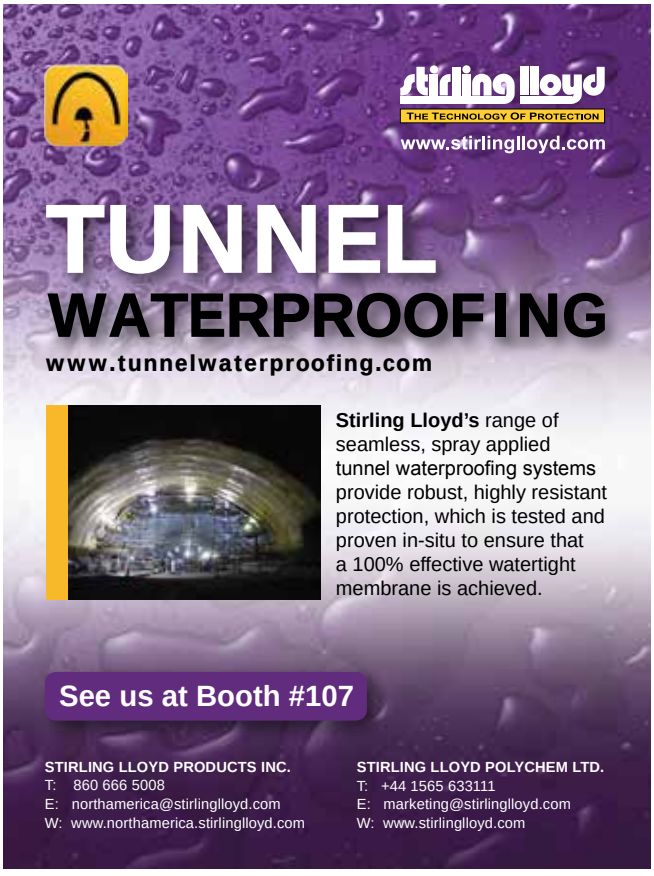
Equipment and Materials, Jet Grouting Equipment and Services, Underground Excavation Services and Equipment

Main Office
45240 Business Ct, Ste 250
Sterling, VA 20166
Phone: (703) 742-0020
Fax: (703) 742-3319
Email: info@schnabel.com
Website: www.schnabel.com

Shannon & Wilson, Inc
Booth 435

Since 1954, Shannon & Wilson has been a pioneer in developing effective underground solutions to complex site development problems. This includes design, plans and specifications, and construction management and support on over 700 soft ground and hard rock tunnel projects, ranging from trenchless to the world's largest bore tunnels. Resources include over 300 staff from the corporate headquarters in Seattle, Washington, and branch offices in Oregon, California, Colorado, Alaska, Missouri, Wisconsin, and Florida. Shannon & Wilson offers services in geotechnical evaluations, tunnel assessments, groundwater and dewatering, instrumentation, environmental, and natural resource assessments.

Products and Services
Consulting Engineers, Consulting Environmental, Engineering Design and Services for Tunnels, Geological, Geotechnical Services and Equipment, Instrumentation Equipment and Services



Main Office
400 N 34th St, Ste 100
Seattle, WA 98103
Phone: (206) 632-8020
Fax: (206) 695-6777
Website: www.shannonwilson.com

Shotcrete Technologies, Inc
Booth 240

STI has been providing innovative Shotcrete products and services to the mining and tunneling industry for over 30 years with our Shot-Tech Robotic Arm which can be mounted on many types of carriers and our industry standard Shotset 250 Liquid Accelerator. STI also has new shaft lining (vertical lining) technology. STI's knowledgeable team of professionals can provide everything from a Shotcrete System design, mix design, to testing and training based on your specific needs from mega projects to small mines.

Products and Services
Shaft Drilling and Raiseboring Equipment, Shotcrete Equipment, Supplies, and Services, Tunnel Lining and Support Materials

Main Office
PO Box 3274
Idaho Springs, CO 80452
Phone: (303) 567-4871
Fax: (303) 567-4605
Email: info@shotcretetechnologies.com
Website: www.shotcretetechnologies.com

SICE INC
Booth 408

See our ad on page 56

Products and Services
Control Systems, Engineering Design and Services for Tunnels

Main Office
2 Alhambra Plaza, Ste 1106
Coral Gables, FL 33134
Phone: (305) 222-7040
Website: www.sice.com

Sika Corporation
Booth 327

See our ad on page 55

Sika Corporation is a global specialty chemicals company. For tunneling, Sika offers a wide variety of products such as chemical admixtures for concrete, repair and protection products, waterproofing products and equipment for shotcrete. Sika's product line for chemical admixtures includes a full range of admixtures, useful for cast-in-place concrete, precast concrete and shotcrete. Sika's repair products include grouts, mortars, adhesives, sealants and structural strengthening systems, and Sika's waterproofing products include membranes, waterstops and drainage systems. For equipment, Sika has a global alliance with Putzmeister and offers a wide range of equipment for dry and wet shotcrete applications.

Products and Services
Concrete Reinforcement, Grouting Services, Equipment and Materials, Shotcrete Equipment, Supplies, and Services

Main Office
201 Polito Ave
Lyndhurst, NJ 7071
Phone: (201) 933-8800
Fax: (201) 933-6225
Website: www.sikausa.com

SOLDATA Inc
Booth 135

Soldata is a leader provider of real time instrumentation monitoring for geotechnical, structural and environmental projects. With almost 20 years of experience, Soldata has demonstrated expertise in large urban tunnel instrumentation projects in cities including Seattle, Washington DC, Los Angeles, Amsterdam, London, Budapest, Barcelona, Toronto, etc. Soldata is currently monitoring the largest TBM project in the world, the Alaskan Way viaduct replacement project, as well as the light rail Northlink Project, both in Seattle.

Products and Services
Computer Hardware and Software, Engineering Design and Services for Tunnels, Geological, Geotechnical Services and Equipment, Instrumentation Equipment and Services

Main Office
1448 Elliott Ave W
Seattle, WA 98119
Phone: (206) 200-8935
Website: www.soldatainc.com

Spendrup Fan Co
Booth 214

Since 1968, Spendrup Fan Co. has designed and manufactured quality vane axial fans and accessories for all types of mining and industrial applications. Spendrup fans are designed to withstand the harshest environments. Fan casings are made of 5/16 steel. Impeller hubs are fabricated from mild steel. Impeller blades are 356-T6 hardness, to resist highly abrasive conditions. Spendrup Fan Co. designs fans to meet client specifications. Spendrup Fan can meet client needs, from MSHA Sch. 2-G, U/L approved explosion proof, marine duty, to fans that provide trouble-free service in high-temperature or corrosive environments.

Products and Services
Tunnel Boring Equipment, Ventilation Systems, Materials and Equipment

Main Office
PO Box 4308
Grand Junction, CO 81502
Phone: (970) 243-3429
Fax: (970) 242-6724
Website: www.spendrupfanco.com

Stirling Lloyd Products, Inc
Booth 107

See our ad on page 58

Stirling Lloyd, market leader in advanced waterproofing technology, has been protecting cut and cover and immersed tube tunnels throughout the world since 1989. Based on proven protection technology, Integritank HF is a rapid cure membrane for the waterproofing of tunnels of a SEM/NATM design. Spray applied and seamless, the unique, innovative system eliminates the risk of weak joints and seams, ensuring that a watertight environment is achieved, reducing ongoing maintenance costs. Integritank HF can radically alter tunnel waterproofing design and lining construction, bringing positive benefits in both time and cost, as well as extending the life of the tunnel.

Products and Services
Tunnel Lining and Support Materials, Water Treatment Plant and Materials

Main Office
152 Rockwell Rd, Bldg A
Newington, CT 6111
Phone: (860) 666-5008
Fax: (860) 666-5106
Website: www.stirlinglloyd.com

Strata Worldwide
Booth 6

See our ad on page 57

Strata specializes in the design and manufacture of emergency refuge chambers, innovative underground roof support systems and state-of-the-art electronic safety technologies which include: • Wireless communications and tracking • Wireless atmospheric monitoring • Proximity detection and collision avoidance • Through-the-earth, post-emergency communications. Strata is committed to the design and development of technologies that are beneficial for today and that lay a foundation for improved solutions in the future. Headquartered in Atlanta, Georgia, USA, the company has service and sales support offices in the mining regions of the U.S., Europe, Australia, South Africa, Mexico and South America.

Products and Services
Safety Products, Tunnel Communication Systems and Equipment

Main Office
8995 Roswell Rd
Sandy Springs, GA 30350
Phone: (770) 321-2526
Fax: (770) 321-2520
Email: info@strataproducts.com
Website: www.strataworldwide.com

Surecrete Inc
Booth 524

See our ad on page 60

Surecrete Inc. specializes in furnishing bagged cementitious materials, mixing and placing equipment, and related accessories to the heavy civil tunnel, geotechnical and mining markets. Its product lines include Nittetsu Super Fine ultrafine cement, rheology modifiers, specialty admixtures, and a complete selection of packaged wet and dry shotcrete, concrete and grout mixes. Surecrete also represents several major equipment manufacturers specializing in the mixing and placing of shotcrete, concrete and grouts.

Products and Services
Grouting Services, Equipment and Materials, Shotcrete Equipment, Supplies, and Services

Main Office
155 NE 100th St, Ste 300
Seattle, WA 98125
Phone: (206) 523-1233
Fax: (206) 524-6972
Website: www.surecrete.com

tacs gmbh
Booth 212

tacs gmbh develops, produces and supplies guidance systems for all kind of TBMs. Specialities of tacs' highly developed acs Guidance System are attractive graphical displays and documentation, calculation of a correction curve to return tangentially to DTA, fully automatic check measurements and particularly the calculation of the optimum position of the tapered ring. New developments integrate AutoCAD drawings for plan view and geological profile and facilities to export ring and TBM data into AutoCAD drawings. We link the disciplines of surveying, civil engineering and machine technology and support these areas and their interaction by manifold coordinated functions and tools.

Products and Services
Laser Guidance Systems

Main Office
Baierbrunner Str 15
Muenchen, 81379 Germany
Phone: 49 89 78576750
Fax: 49 89 785767520
Email: mail@tacsgmbh.de
Website: www.tacsgmbh.de

Team Mixing Technologies, Inc

Booth 314

For over 40 years Team Mixing Technologies has provided fully automated material handling systems for TBM bi-component grouts, bentonite slurries and grout injection as well as for shotcrete, concrete and mining backfill. TMT manufactures colloidal mixers, pumping and delivery systems, as well as the automation and controls. Concepts are specifically tailored to the customer's needs and include complete engineering, design and fabrication of all mechanical, structural and electrical systems. Services range from preliminary engineering and case studies through to hands-on commissioning and field training with complete CAD documentation and follow-up.

Products and Services

Conveyor Equipment and Systems, Grouting Services, Equipment and Materials, Jet Grouting Equipment and Services, Pumps and Pumping Equipment, Soil Conditioning Equipment and Materials

Main Office

#1A 30528 Great Northern Ave
Abbotsford, BC V2T 6H4 Canada
Phone: (604) 556-7225
Fax: (604) 556-7215
Website: www.teammixing.com

Technical Tunnelling Components LTD (TTC)

Booth 504

Technical Tunnelling Components has over 40 years of experience manufacturing and supplying segment accessories such as connection bolts, grout/lifting sockets, segment packers and grommets along with the award winning Dowelock connection and alignment system, now with high shear options. TTC truly is the one stop shop for all precast segmental fixing and grouting systems. The in-house design and manufacturing capabilities that Tunnelling Accessories and Bosworth Plastics have can also offer bespoke products for challenging situations as well as the standard segment accessories. TTC are Supplying components worldwide with an impressive product portfolio along with an excellent service record.

Products and Services

Grouting Services, Equipment and Materials, Precast Concrete Linings, Tunnel Lining and Support Materials

Main Office

Unit K Radius Ct, Tungsten Pk
Hinckley, Leicester LE10 3BE
United Kingdom
Phone: 44 0 1455 234401
Fax: 44 0 1455 250578
Website: www.ttcltd.org

TEI Rock Drills, Inc

Booth 11

TEI Rock Drills is an American manufacturer of drill rigs and drill components. Electric limited access rigs and drilling attachments are available for all types of drilling involved with tunneling. Drill components such as drifters, feeds, clamp and breakers are available to contractors and OEMs. TEI is your reliable source for quality drilling equipment.

Products and Services

Drilling Services and Equipment, Hydraulic Hammers and Drills, Mining Equipment, Rock Drills, Underground Excavation Services and Equipment

Main Office

PO Box 1309
Montrose, CO 81402
Phone: (970) 249-1515
Fax: (970) 249-1999
Website: www.teirockdrills.com

Tenbusch, Inc

Booth 337

Tenbusch, Inc. designs and manufactures custom tunneling and pipe jacking systems. Products include: shields, excavators, conveyors, spoil carts and track, jacking frames, hydraulic power units, bentonite/polymer lubrication systems, and backstops. Tenbusch also manufactures sliplining systems and pipe carriers. In addition to the fabrication and manufacture of high quality heavy equipment, it offers reconditioning and refurbishment of used heavy equipment, support and training with design and problem solving services centered around over 40 years experience with hydraulics, and underground construction equipment. Over 15 years in mechanical design, mechanical engineering, and stress analysis, solid modeling and 3-D CAD design capabilities.

Products and Services

Air Locks and Bulkheads, Conveyor Equipment and Systems, Fabrication Materials, Mining Equipment, Soft Ground Shields, Tunnel Boring Equipment



Main Office
PO Box 417
Lewisville, TX 75067
Phone: (972) 221-2304
Fax: (972) 221-2498
Email: info@tenbusch.com
Website: www.tenbusch.com

TerraDol Civil
Booth 9

Located in Englewood Cliffs, New Jersey, TerraDol Civil is specialized in providing innovative products and cutting edge technologies for Civil and Marine Construction. We are currently supplying diversified construction materials including Fabulex (Expandable Rock Bolting System), ReEn Hi-FA (Non-Dispersion Grout Admixture), and construction steels for marine and inland structures. We also provide innovative Bi-Directional Pile Load Test (BD-PLT) and Geotechnical/Geophysical exploration services.

Products and Services
Concrete Mixing and Transportation Equipment, Concrete Reinforcement, Ground Improvement Equipment and Services, Grouting Services, Equipment and Materials

Main Office
467 Sylvan Ave
Englewood Cliffs, NJ 7632
Phone: (201) 568-1951
Fax: (201) 568-1972
Email: info@terradol.com
Website: www. terradol.com

Thompson Pipe Group
Booth 3

Products and Services
Microtunneling Equipment, Tools, and Supplies, Water Treatment Plant and Materials

Main Office
3009 Laurel Ave
Rialto, CA 92377
Phone: (909) 434-1888
Fax: (909) 434-1895
Email: babasiri@ktipipe.com
Website: www.flowtitepipe.com

Trelleborg Ridderkerk BV
Booth 334

Trelleborg Ridderkerk is the customer's partner in the design and production of engineered rubber products. Trelleborg Ridderkerk's focus is on the markets of civil engineering, offshore oil and gas, dredging, sewage, building and industry. Its products seal damp and protect in demanding industrial environments worldwide. Trelleborg Ridderkerk is unrivalled in seal design and elastomer technology and is the only company in the world supplying seals for immersed tube, bored tunnels and cut and cover. The company is the worlds leading manufacturer of Gina gaskets and Omega seals and are prominent suppliers of tunnel segment gaskets.

Products and Services
Engineering Design and Services for Tunnels, Precast Concrete Linings, Safety Products, Tunnel Boring Equipment, Tunnel Lining and Support Materials, Underground Utility Materials and Operations

Main Office
PO Box 4007
Ridderkerk, 2980GA Netherlands
Phone: 31 (0) 180 495555
Fax: 31 (0) 180 433080
Website: www.trelleborg.com

Trolex Limited/ GEO-Instruments
Booth 306

For half a century, Trolex has been supplying and installing environmental monitoring systems along the length of tunnels, and on tunnel boring machines. Our intrinsically safe and cost-effective solutions are the first port of call for those looking to keep cabling, installation and maintenance costs to a minimum. Established in 2003, GEO-Instruments specialises in assisting geotechnical and civil engineers to monitor any movement in structures and in the earth. They manufacture and supply sensors and systems to measure movement, pressure, vibration and other environmental changes in structures, soil, and rock.

Products and Services
Environmental Control Equipment and Supplies, Instrumentation Equipment and Services, Safety Products, Tunnel Boring Equipment

Main Office
Newby Rd, Hazel Grove
Stockport, Cheshire SK7 5DY
United Kingdom
Phone: 44 (0) 161 483 1435
Email: sales@trolex.com
Website: www.trolex.com

Tunnel Business Magazine (TBM)
Booth 5

TBM: Tunnel Business Magazine provides the North American tunneling industry with a trade magazine focusing on North American topics, projects and news. From large diameter tunneling to microtunneling, Tunnel Business Magazine, published by Benjamin Media, Inc., reports on the issues and topics important to the North American tunneling contractor, engineer and owner. Free subscriptions are available.

Products and Services
Educational, Publishers

Main Office
Benjamin Media, Inc
Brecksville, OH 44141
Phone: (330) 467-7588
Fax: (330) 468-2289
Website: www.tunnelingonline.com

Tunnels & Tunnelling
Booth 1

With more than 40 years of service to the tunnelling industry, and packed with information about the business its customers are in, Tunnels & Tunnelling International remains the leading underground construction magazine worldwide. Since 1999 T&T offers T&T North America, a bi-monthly magazine dedicated to its customers' regional market, and the official publication of the Tunnelling Association of Canada (TAC). Each edition of T&T informs tunnelling professionals on every aspect of underground construction in five continents. Readers include consulting engineers, clients, contractors and manufacturers in 90 countries. Stay abreast of all developments in the tunnelling industry by subscribing to T&T.

Products and Services
Educational, Publishers

Main Office
John Carpenter House
London, EC4Y 0BS United Kingdom
Phone: 44 (0) 20 7406 6584
Fax: 44 (0) 20 7936 6813
Website: www.tunnelsonline.info

URS Corp
Booth 426

See our ad on page 62

URS is a world leader in infrastructure engineering and is proud to be a worldwide provider of tunnel planning, design and construction services for its clients. From water and wastewater tunnels to viaducts, subways and nuclear waste repository tunnels, the URS National Tunnel Practice has proven that URS is committed to developing solutions that are thorough, practical, and cost-effective.

Products and Services
Consulting Engineers, Engineering Design and Services for Tunnels, Geological, Geotechnical Services and Equipment, Underground Excavation Services and Equipment

Main Office
277 W Nationwide Blvd
Columbus, OH 43215-2562
Phone: (614) 464-4500
Fax: (614) 464-0588
Website: www.urscorp.com

VMT GmbH
Booth 131

VMT supplies tailor-made solutions, services, navigation- and monitoring systems to the tunnelling industry since 1994. Development of specific systems for the guidance of Tunnel Boring Machines in segmental lined and pipe jacked tunnels and as well for conventional tunnelling has been the major aspect of product development to date. For each project, VMT provides a documentation, storage and monitoring system with evaluation and analysis functions. Sales and rental of this equipment around the world has established VMT as the leading Survey Technology Supply Company. Subsidiaries on four continents assure close and quick support to customers worldwide.

Products and Services
Engineering Design and Services for Tunnels, Geological, Geotechnical Services and Equipment, Laser Guidance Systems, Roadheaders, Survey Equipment and Lasers, Tunnel Communication Systems and Equipment

Main Office
Stegwiesenstrasse 24
Bruchsal, 76646 Germany
Phone: 49 7251 9699 0
Fax: 49 7251 9699-22
Email: info@vmt-gmbh.de
Website: www.vmt-gmbh.de

W. R. Grace & Co
Booth 226

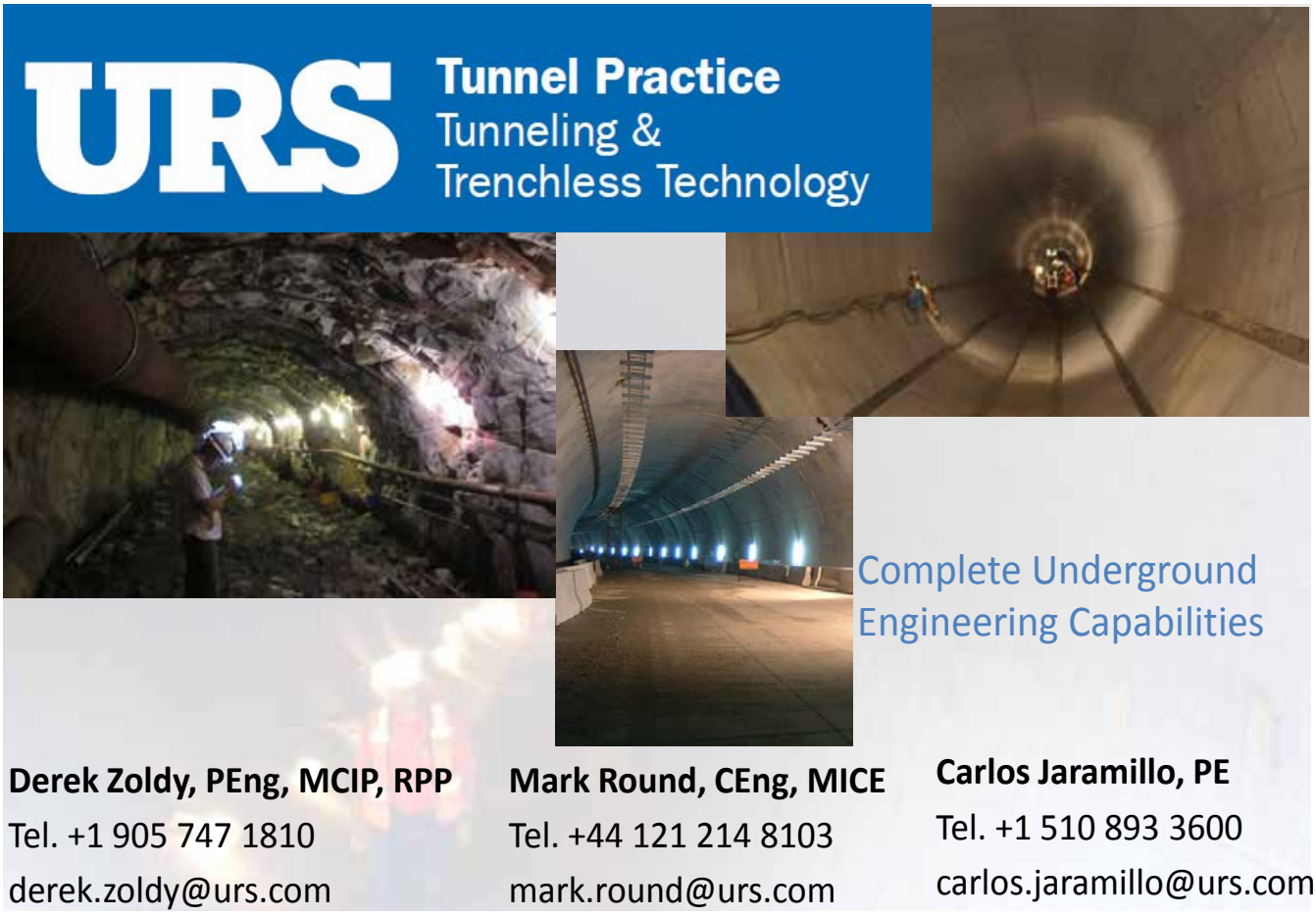
W. R. Grace & Co., NYSE: GRA, is a world-leading provider of specialty construction materials, systems and services, including advanced waterproofing solutions, waterstops which are both injectable and hydrophilic, fire protection systems, and masonry products and additives for cement processing. The company is also a leader in concrete admixtures, shotcrete, fibers, surface treatments and liquid pigments that make concrete stronger, longer lasting, crack resistant, aesthetically pleasing and cost efficient. Grace brings years of construction products experience to the tunneling market, providing a complete offering of products and expertise to solve the most demanding waterproofing, fire protection, and concrete design needs.

Products and Services
Engineering Design and Services for Tunnels, Ground Improvement Equipment and Services, Grouting Services, Equipment and Materials, Shotcrete Equipment, Supplies, and Services, Tunnel Lining and Support Materials, Water Treatment Plant and Materials

Main Office
62 Whittemore Ave
Cambridge, MA 2140
Phone: (646) 872-1378
Website: www.graceconstruction.com

Williams Form Engineering Corp
Booth 203

Williams Form Engineering Corporation has been providing threaded steel bars and accessories for rock, soil and concrete anchors, post-tensioning systems, and concrete forming hardware systems in the construction industry for over 85 years. Its rock and soil anchor product line includes the Spin-Lock mechanical rock anchors, polyester resin anchors, multiple corrosion protection anchors, soil nails, strand anchors, Manta Ray soil anchors, Geo-Drill Hollow-Bar anchors, micro piles. For concrete



anchoring Williams Form offers Spin-Lock anchors, undercut anchors, reusable anchors and cast-in-place anchors. It also has a full line of All-Thread rebar for tie backs, micro piles and post-tensioning.

Products and Services
Concrete Reinforcement, Geological, Geotechnical Services and Equipment, Tunnel Lining and Support Materials

Main Office
8165 Graphic Dr
Belmont, MI 49306
Phone: (616) 866-0815
Fax: (616) 866-1890
Email: williams@williamsform.com
Website: www.williamsform.com

World Tunnelling Magazine/ Aspermont Media
Booth 7

For over 25 years World Tunnelling has been at the forefront of publishing information on the most up-to-date products, significant projects and latest technologies in the world of underground construction. International contributors, ranging from technical associations, consultants, contractors and product manufacturers, have brought their detailed insights to the page since 1988. Each issue examines current projects and market conditions within a particular geographic region. Throughout the year World Tunnelling also provides articles on a wide range of subjects, including tunnel boring machines and drill and blast techniques.

Products and Services
Publishers

Main Office
4th Fl, 120 Old Broad St
London, EC2N 1AR United Kingdom
Website: www.world-tunnelling.com

Zed Tunnel Guidance Ltd
Booth 316

ZED develops and manufactures TBM navigation/guidance systems for installation on most types of machine, and used worldwide. The equipment undergoes continuous, but controlled redesign, to incorporate the latest and most appropriate advances in electronic technology, improving reliability and robustness. Windows Embedded Standard 7 is the OS which, with ZEDs specific build configuration, provides good stability and a reliable platform on which to run its suite of applications. Product quality enables ZED, a small company, to concentrate on R&D, enhancing the current system and expanding into other areas within the tunnelling industry where new instrumentation is required.

Products and Services
Instrumentation Equipment and Services, Laser Guidance Systems, Microtunneling Equipment, Tools, and Supplies

Main Office
Unit 1 Russell House, Molesey RD
Walton on Thames, Surrey KT12 3PJ United Kingdom
Phone: 44 (0) 1932 251 440
Fax: 44 (0) 1932 244 971
Website: www.zed-tg-co.uk

PRODUCTS & SERVICES

Air Locks and Bulkheads
Ballard Diving & Hyperbaric Services - Booth 341
MineARC Systems - Booth 428
Reimers Systems, Inc - Booth 431
Tenbusch, Inc - Booth 337

Blasting Services and Supplies
Orica USA Inc - Booth 403

Computer Hardware and Software
Babendererde Engineers, LLC - Booth 534
Rocscience, Inc - Booth 512
Itasca Consulting Group, Inc - Booth 330
PLAXIS - Booth 410
SOLDATA Inc - Booth 135

Concrete Mixing and Transportation Equipment
Amix Systems Ltd - Booth 430
King Shotcrete - Booth 210
Mining Equipment Ltd - Booth 315
Normet Americas, Inc - 402
RDH Mining Equipment - Booth 2
TerraDol Civil - Booth 9

Concrete Reinforcement
Agru America, Inc. - Booth 502
Williams Form Engineering Corp - Booth 203
Bekaert Corp - Booth 413
David R. Klug & Associates, Inc - Booth 220
Helix Steel - Booth 312
HIC Fibers, Inc - Booth 333
Elasto Plastic Concrete - Booth 404
Euclid Chemical Co - Booth 318
Halfen Anchoring Systems - Booth 421
Heintzmann Corp - Booth 328
King Shotcrete - Booth 210
Maccaferri Inc - Booth 339
Normet Americas, Inc - 402
Sika Corporation - Booth 327
TerraDol Civil - Booth 9

Construction - Contracting Services
Ballard Diving & Hyperbaric Services - Booth 341
Bauer Foundation Corp - Booth 238
c2pm - Booth 206

Hayward Baker Inc - Booth 205
Jacobs Associates - Booth 229
Moretrench - Booth 326
Schnabel Foundation Co - Booth 520

Consulting Engineers

AECOM - Booth 336
Amberg Engineering
(North America), Inc. - Booth 230
Babendererde Engineers, LLC - Booth 534
Baroid Industrial Drilling Products
(IDP) - Booth 215
c2pm - Booth 206
CDM Smith - Booth 510
HNTB Corporation - Booth 224
ILF Consultants, Inc - Booth 311
Itasca Consulting Group, Inc - Booth 330
Gall Zeidler Consultants - Booth 418
Condor Earth Technologies, Inc - Booth 304
Dr. Sauer & Partners Corp - Booth 235
Everest Equipment Co - Booth 536
Geocomp/GeoTesting Express - Booth 231
Gomez International, Inc - Booth 437
Jacobs Associates - Booth 229
Jennmar Corp - Booth 508
Lachel & Associates, Inc - Booth 514
Maccaferri Inc - Booth 339
MWH Global - Booth 518
Nexans AmerCable, Inc - Booth 141
Parsons Brinckerhoff - Booth 331
Paul C. Rizzo Associates, Inc - Booth 239
Reimers Systems, Inc - Booth 431
Shannon & Wilson, Inc - Booth 435
URS Corp - Booth 426

Consulting Environmental

HNTB Corporation - Booth 224
Itasca Consulting Group, Inc - Booth 330
Condor Earth Technologies, Inc - Booth 304
OxyHeal Tunneling Group, Inc - Booth 406
Shannon & Wilson, Inc - Booth 435

Control Systems

Amix Systems Ltd - Booth 430
BPS - Bakersfield Pipe & Supply - Booth 105
Pemco Corp - Booth 335
SICE INC - Booth 408
Reimers Systems, Inc - Booth 431

Conveyor Equipment and Systems

Luff Industries - Booth 414
Gomez International, Inc - Booth 437
Team Mixing Technologies, Inc - Booth 314
Tenbusch, Inc - Booth 337
The Robbins Co - Booth 425

Drilling Services and Equipment

Cascade Drilling L.P. - -Booth 436
Baroid Industrial Drilling Products
(IDP) - Booth 215
Bauer Foundation Corp - Booth 238
Ruen Drilling, Inc - Booth 419
Crux Subsurface, Inc - Booth 441
Derrick Equipment Co - Booth 213
Hayward Baker Inc - Booth 205
Layne Geo - Booth 109
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