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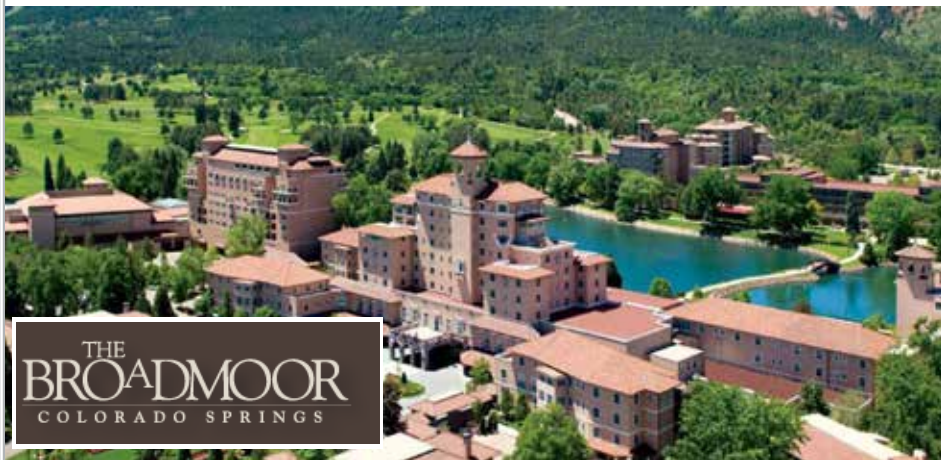


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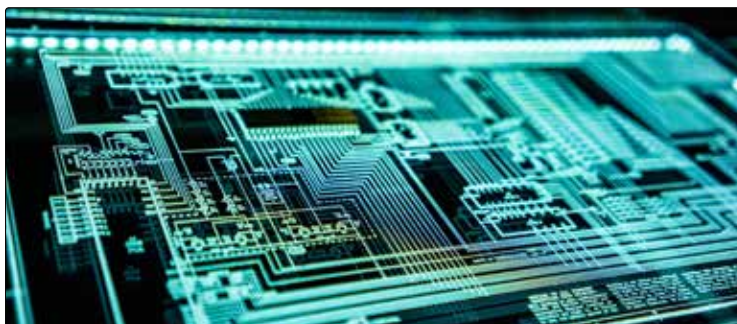
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Cover

On March 1, Marc LeVier was installed as the 2023 SME President. LeVier built a successful career as a leader and team builder. On page 14 LeVier shares his thoughts about the state of the mining industry, his career and his vision for the future of SME. On page 19 Weston Hartzell and Michael Moats write about the extraction of critical materials from steelmaking wastes. Cover design by Ted Robertson.



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DOI protects lands in Minnesota from development

THE U.S. Department of the Interior issued a 20-year mining moratorium on 225,000 acres of federal land in Minnesota near the Boundary Waters.

The decision appears to be in contrast to the Biden administration's stated goal of creating a domestic supply chain of critical minerals as it potentially blocks the development of the proposed \$1.7 billion Twin Metals project in Ely, south of the Boundary Waters and within the mineral withdrawal area.

The Twin Metals project would create an underground copper-nickel mine that would also produce cobalt and platinum-group metals from the Maturi deposit, which is part of the Duluth Complex geologic formation.

"The announcement from the U.S. Department of the Interior today to withdraw federal lands from mineral development is a step in the wrong direction and will make it harder to achieve President Biden's own climate and domestic content goals. As the Minnesota Legislature simultaneously is advancing a bill prioritizing 100 percent carbon-free energy by 2040, this federal action is also severely limiting how much of a

role Minnesota can play in reaching that goal," Julie Lucas, executive director of MiningMinnesota told *Mining Engineering*. "We cannot produce the wind towers, solar panels, electric-vehicle batteries, charging infrastructure or energy transmission our state and country need to meet these climate goals without a massive increase in the amount of critical minerals being produced worldwide. We should be prioritizing the safe and responsible development of these minerals, not putting them in a lockbox to ensure they can't be used."

Two federal mineral leases held by Twin Metals were canceled by the Biden administration last year. Twin Metals has sued to have those leases reinstated; however, even if it prevails, the mineral withdrawal puts additional federal leases that Twin Metals had hoped to obtain off limits, Minnesota Public Radio reported.

The withdrawal does not impact the proposed PolyMet Mine, which lies within the Lake Superior watershed, south of the withdrawal area.

The decision to withdraw lands followed more than a year of analysis by the Bureau of Land Management

and U.S. Forest Service of the potential environmental and cultural impacts of mining in the region upstream from the Boundary Waters, and the review of 225,000 public comments.

"Protecting a place like Boundary Waters is key to supporting the health of the watershed and its surrounding wildlife, upholding our Tribal trust and treaty responsibilities, and boosting the local recreation economy," said Secretary of the Interior Deb Haaland in announcing her decision.

"With an eye toward protecting this special place for future generations, I have made this decision using the best-available science and extensive public input."

The decision limits the mining of a significant portion of the Duluth Complex, one of the largest undeveloped deposits of copper, nickel, cobalt and other platinum-group metals in the world.

An Interior Department official speaking on background said the Biden administration is committed to developing a strong domestic mineral supply chain, and supports responsible mining to develop those critical minerals. ■

US politicians join push for copper to be critical mineral

THE COPPER Development Association has urged the U.S. government to consider copper as a critical mineral, joining a list of 50 other minerals already identified as vital by the government. The association's members include some of the biggest copper producers including Rio Tinto Group, BHP Group and Freeport-McMoRan Inc., as well as fabricators such as Mueller Industries Inc.

The group got some political backing recently when Senator Kyrsten Sinema, an Independent from Arizona, sent a letter with other lawmakers urging Interior Secretary Deb Haaland to "revisit and reconsider the designation of copper as a critical mineral." Signers included other senators whose home states are hubs of copper production and manufacturing, including Mark

Kelly of Arizona, Joe Manchin of West Virginia, Indiana's Mike Braun, Raphael Warnock of Georgia and Mitt Romney of Utah.

"This should be a no-brainer," Sinema told *Bloomberg*. "We have major gaps in both our ability to mine and process these minerals to ensure our energy security for the future, and the administration knows how important copper is to our domestic and national security."

The U.S. critical minerals list is updated every three years and includes key battery metals needed for electric-vehicle production such as nickel, lithium and zinc. The latest update, in 2022, did not include copper despite the lobbying efforts, though it did add nickel and zinc. The senators are calling on the White House to skip the usual three-year review and add copper to the list as

soon as possible.

Some of the world's largest miners and metals traders have warned that a massive shortfall will emerge for copper, holding back global growth and throwing international climate goals off course given their importance to electrifying economies.

The letter warns of a "significant increase in the supply risk" of copper driven by economic and geopolitical events like the war in Ukraine.

"Given the enormous investment required, the time lag for new sources of supply, and projected demand, time is of the essence," the letter said.

Separately, Representatives Brian Higgins, a Democrat of New York, and Robert Latta, a Republican of Ohio signed a Feb. 2 letter also calling on Haaland to immediately reconsider adding copper as a critical mineral. ■



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USGS records \$3.6 billion jump in production; A total value of \$98.2 billion was produced in 2022

U.S. MINES PRODUCED approximately \$98.2 billion in nonfuel mineral commodities in 2022 — an estimated \$3.6 billion increase over the 2021 revised total of \$94.6 billion — the U.S. Geological Survey (USGS) announced.

This information comes from the 28th annual “USGS Mineral Commodity Summaries” report, released Jan. 31 by the USGS National Minerals Information Center. The report is a comprehensive source for estimates of 2022 mineral data and includes information on the domestic industry structure, government programs, tariffs, world production and five-year salient statistics for nonfuel mineral commodities that are important to the U.S. economy and national security.

The report covers more than 90 nonfuel mineral commodities monitored by the USGS, including mineral commodities such as cement, iron ore, and sand and gravel; precious metals such as gold and silver; as well as rare earth minerals such as lanthanum, neodymium and dysprosium. Nonfuel mineral commodities are used in every facet

of modern life from construction to the consumer-electronics, aerospace, renewable-energy and healthcare industries. The annual USGS report identifies events, trends and issues in the domestic and international minerals industries that impact production and consumption.

“Industries that use nonfuel mineral materials created an estimated \$3.64 trillion in value-added products in 2022, which represents a 9 percent increase from 2021,” said Steven M. Fortier, USGS National Minerals Information Center director. “Decision-makers and leaders in both the private and public sectors rely on the crucial, unbiased statistics and data provided by the USGS in the Mineral Commodity Summaries to make business decisions and determine national policy.”

The increase in consumption of nonfuel mineral commodities compared with that in 2021 is attributed to the continued recovery of markets from the impacts of the global coronavirus pandemic in 2020. Global supply chains and the often-volatile mineral commodity markets were significantly disrupted by the

pandemic, especially in the first half of 2020. However, for the United States, the second half of 2020 and all of 2021 saw a rebound in the demand for and prices of nonfuel mineral commodities. This upward trend continued in 2022 with consumption of many mineral commodities now near or exceeding prepandemic levels.

The \$98.2 billion value of nonfuel mineral commodities produced by U.S. mines in 2022 included other industrial minerals and natural aggregates, as well as ferrous and nonferrous metals. The estimated value of U.S. production of all industrial minerals in 2022 was \$63.5 billion, which is about 65 percent of the total value of U.S. mine production. Crushed stone was the leading nonfuel mineral commodity domestically produced in 2022, accounting for 21 percent of the total value of U.S. mine production.

U.S. metal mine production in 2021 was valued at an estimated \$34.7 billion, 6 percent lower than the revised value in 2021. The principal contributors to the total value of metal mine production in 2022 were copper (33 percent), gold (28 percent), iron

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Mining workforce issues present hurdle while industry faces high demand

THE MINING industry is facing a human resources crisis in the United States at a time when demand for the products it produces is on the rise. Freeport-McMoRan is among the mining companies struggling with staffing issues.

After reporting better than expected quarterly earnings, president Kathleen Quirk told investors that “We could have in 2022 produced more (copper) if we were fully staffed. And I believe that is the case again this year.”

Reuters reported that Freeport-McMoRan currently has 1,300 job openings in the country, more than 10 percent of its U.S. workforce. The

company’s U.S. copper production fell 7 percent last quarter from the same period in 2021. For 2023, the company expects its U.S. copper output to slip nearly 1 percent from 2022 levels.

Executives noted that they are not seeing the same trends in South America or Indonesia, where Freeport also operates large mines.

“Our work is hard work. And it’s harder to drive a big haul truck (at a copper mine) than it is to drive an Amazon or UPS or FedEx truck,” said chief executive Richard Adkerson, who called the worker shortage a “strategic challenge” for the Phoenix-

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Newmont offers \$16.9 billion for Newcrest Mining; Deal would merge two senior-level gold companies

NEWMONT CORP. made an initial \$16.9 billion offer for Newcrest Mining that would combine two of the gold mining sector's top senior producers. Newcrest rejected the offer on Feb. 6, however. Newcrest indicated it would consider additional offers from Newmont.

If the deal is completed, the all-share deal would be the largest mining takeover and the third largest corporate buyout in Australian history, according to Refinitiv data.

"Newmont's proposal to combine with Newcrest is on the basis of 0.380 Newmont shares per Newcrest share, which would result in the combined company being 30 percent owned by Newcrest and 70 percent owned by Newmont. This represents a compelling opportunity for the shareholders of both companies to share in the upside

of putting together two complementary businesses," Newmont wrote in a press release.

Reuters reported that Newcrest's previous chief executive, Sandeep Biswas, recently stepped down leaving the company in search of new leadership. The proposed deal comes at a time in which global interest rates are expected to peak this year and turn down, improving the outlook for gold prices.

The Australian gold miner said that it was considering the proposal. Newmont, the world's biggest gold producer by market value and ounces produced, described the combination as "a powerful value proposition."

"We believe a combination of Newmont and Newcrest presents a powerful value proposition to our respective shareholders, workforce

and the communities in which we operate," said Tom Palmer, president and chief executive officer of Newmont. "The proposed transaction would join industry-leading portfolios of assets and projects to create long-term value across the combined global business, and we welcome the consideration of Newcrest's board of directors."

Newmont remains fully committed to acting in the best interest of Newmont shareholders. Newmont and its board advises shareholders need not take any action at this time as there can be no certainty that a transaction will be concluded.

Newmont has engaged BofA Securities, Centerview Partners LLC and Lazard as its financial advisers, and King & Wood Mallesons and White & Case LLP as its legal advisers. ■

Surge in coal prices is a win for some investors; Energy crisis leads to increased demand for coal

THE PRICE OF thermal coal has more than tripled in less than two years as the global energy crisis and Russia's invasion of Ukraine have spurred high demand for coal. Some hedge funds that bet on the reliability of coal have been rewarded.

According to a report from the *Financial Times*, hedge funds including Third Point, Makuria Investment Management and Odey Asset Management have reaped windfall profits thanks to the spike in prices and the profits made by miners. It has also added to the debate among investors about how they should view coal.

There has been many reports of large investors dropping investments in coal and other fossil fuels in favor of environmental, social and governance (ESG) policy while other investors say the shift to clean energy will take decades and have stuck with coal.

"The transition to green energy will not happen overnight," Petra Dismorr, chief executive of consultancy NorthPeak Advisory told the *Financial Times*. "This has raised a divide for many allocators in assessing which

stocks they can or cannot buy," she said.

Daniel Loeb's Third Point and Odey Asset Management are among a number of funds that chose London-listed Glencore, the world's most profitable coal company, as a way of benefiting from demand for the fuel. Glencore shares are up more than 40 percent since the start of last year and trading near a record high.

Glencore is just one of a number of companies that have seen an uptick in profits. Profits at the world's 20 biggest coal miners tripled last year to more than \$97 billion, with Glencore earning \$13.2 billion in the 12 months to June 2022, and China Shenhua making \$12.2 billion. Among the shares that have outperformed since the start of last year are Whitehaven Coal, up about 200 percent, and Peabody Energy, which has surged more than 150 percent.

Coal is still used to produce more than one-third of the world's electricity, and is the primary source of power in fast-growing economies such as India, China and Indonesia.

In Europe, which aims to cut

emissions by 55 percent by 2030, coal has made a comeback because of the squeeze on Russian gas supply. Germany, for instance, whose coalition government includes the Green party, has extended the life of its coal-fired power stations to avoid a potential energy crisis. In December the UK gave the go-ahead to the first new coal mine in 30 years and in October, RWE announced plans to expand to the Garzweiler coal mine in Germany.

In December, the International Energy Agency (IEA) released its Coal 2022 report in which it found that global coal consumption is likely to hit an all-time mark of 8 Gt (8.8 billion st) consumed in a single year.

The IEA report, which forecasts the world's coal consumption, said coal use is set to rise by 1.2 percent and pass the previous record that was set in 2013. It forecast that consumption levels will remain relatively flat through 2025 as declines in mature markets are offset by continued robust demand in emerging Asian economies. This means coal will likely remain in the global energy mix for years to come. ■

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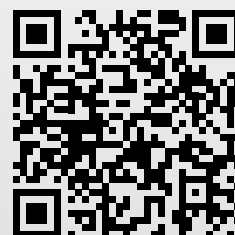


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British Columbia sees record exploration investment; Mineral production in Canadian province reached \$18.2 billion

DURING THE opening ceremony of the Association of Mineral Exploration (AME) Roundup conference in Vancouver, British Columbia, Canada, Premier David Eby said British Columbia had record spending on mineral exploration in 2022 with eight new mines or mine expansions in the works.

Eby told the conference that \$740 million was spent in mineral exploration in British Columbia in 2022 — a record — and mineral production in British Columbia is expected to be a record \$18.2 billion.

Business in Vancouver reported that Eby's update represents a \$4.3 billion increase over 2021. That increase in value over 2021 was largely due to high metallurgical coal prices. Gordon Clarke of the British Columbia Geological Survey's development office told *Business in Vancouver* that steelmaking coal prices hit a high of US\$670/t last year, and remains relatively high at close to US\$300/t. British Columbia has seven operating metallurgical coal mines.

Eby said there was an 84 percent

increase in copper exploration in 2022, much of that concentrated in northwest British Columbia in the so-called Golden Triangle.

Jonathan Price, new chief executive officer of Teck Resources, which operates the Highland Valley Copper mine, said the estimated global demand for copper will grow by 4.7 Mt (5.3 million st) by 2030, thanks to increased demand from the energy transition and greater urbanization.

"To put that into perspective, Teck's Highland Valley Copper mine here in British Columbia is Canada's largest copper mine," Price said. "4.7 Mt (5.2 million st) would be the equivalent of building another 35 Highland Valley Copper mines in just seven years."

Eby noted that a commitment to speed up the permitting process for housing should speed things up for resource industries like exploration and mining as well.

Business in Vancouver reported that Eby warned that the political landscape is changing as a result

of government commitments to reconciliation with First Nations. For one thing, the Mineral Tenure Act is likely going to have to be amended as a result of what Eby called "a very serious legal challenge" by First Nations.

First Nations pressing for changes to the act want to be notified when anyone files a mineral claim in their traditional territory. That has created some concerns for prospectors who consider mineral claims a form of intellectual property, and therefore like to keep claims secret.

The New Democratic Party government has recently struck agreements with First Nations that essentially make them co-regulators. A consent-based decision-making framework developed with the Tahltan First Nation last year is one example. Expect to see more such agreements going forward, Eby said. He urged prospectors and exploration companies to work with First Nations to gain their consent when doing exploration and prospecting in their traditional territories. ■

USGS: 13 minerals worth more than \$1 billion

(continued from page 6)

ore (15 percent), zinc (9 percent) and molybdenum (5 percent).

There were 13 mineral commodities produced in the United States valued at more than \$1 billion each. These commodities were, in order of descending value, crushed stone, cement, copper, construction sand and gravel, gold, industrial sand and gravel, iron ore, zinc, salt, lime, phosphate rock, molybdenum and soda ash.

In 2022, the top 10 producing states were, in descending order of rank, Arizona, Nevada, Texas, California, Minnesota, Alaska, Florida, Utah, Michigan and Missouri.

Other key highlights from the report include:

- On Feb. 24, 2022, the USGS published the 2022 Final List of

Critical Minerals in the Federal Register (87 FR 10381). The 2022 list of critical minerals, which revised the critical minerals list published in 2018 (83 FR 23295), included 50 mineral commodities instead of 35 mineral commodities or mineral groups. The report also outlines several recent initiatives, projects and legislation focused on securing American supply chains and supporting domestic production projects in the United States Critical Minerals Update section.

- In October, commissioning began at a cobalt-copper-gold mine and mill in Idaho, where cobalt concentrate will be produced. This mine and one in Morocco are the only mines in the world where cobalt is the principal product.
- In 2022, the USGS invested \$74

million in several projects to collect geochemical, geological and geophysical data to improve mapping of critical mineral resources across the country. Substantial funding for the projects came from the Bipartisan Infrastructure Law. The studies were also funded through the USGS Earth Mapping Resources Initiative, a collaborative project between the USGS and state geological surveys to collect and modernize the nation's geologic mapping and data resources.

- Domestically, \$42 billion of metals and mineral products were recycled including metals such as copper, gold, iron and steel scrap, and platinum-group elements to supply domestic consumption. This was a slight decrease in value compared with that in 2021. ■

GM to make \$650 million investment in Thacker Pass; Automaker commits to development of lithium in Nevada

GENERAL MOTORS Co. (GM) is among numerous automakers positioning itself to secure critical minerals needed for batteries for electric vehicles.

In January, GM announced plans to invest \$650 million in Lithium Americas, which is working to develop the Thacker Pass Mine in Nevada. The investment would secure access to lithium from the proposed mine. The deposit is the largest known source of lithium in the United States and when processed could provide enough lithium for GM to produce as many as 1 million electric vehicles (EV) per year.

“Direct sourcing of critical EV raw materials and components from suppliers in North America and free-trade-agreement countries helps make our supply chain more secure, helps us manage cell costs and creates jobs,” GM chair and chief executive officer Mary Barra said in a statement.

“It’s an exciting milestone, and we couldn’t ask for a better organization than General Motors to become our largest investor,” Lithium Americas president and chief executive officer Jonathan Evans told *CNBC*. “GM shares our commitment to meaningfully advancing the energy

transition, and I’m confident that together we can make Thacker Pass a major player in a secure, integrated North American supply chain from critical battery materials to EVs.”

The \$650 million from GM will be delivered in two portions. The money for the first tranche will be held in escrow pending the conclusion of a record of decision ruling currently pending in U.S. District Court.

In February, GM continued its search to source material as it advanced to the next round of bidding for a minority stake in Brazilian mining giant Vale SA’s base metals unit. According to a report from Bloomberg, people familiar with the matter said the bid for a stake in Vale underscores the automakers’ desire for easy access to the materials needed for EV batteries.

Bloomberg News reported in November that Saudi Arabia’s Public Investment Fund and Japanese trading house Mitsui & Co. were also weighing making offers for a slice of the nickel and copper operations. Deliberations are ongoing and Vale has made no final decisions about a sale, according to reports.

Representatives for GM and

Vale declined to comment on the *Bloomberg* report.

Vale is separating the base metal assets from its iron ore operations and wants to unveil a strategic partner for the new entity in the first half of 2023, its management personnel said last year. The Rio de Janeiro-based company is making the move as a shift away from fossil fuels spurs demand for materials that are key to the manufacture of EV batteries.

Automakers have been stepping up efforts to lock in supplies of nickel and copper, including through direct deals with producers of these metals. Vale is already a direct supplier of nickel for Tesla Inc. batteries. GM reached its own agreement with Vale last year to buy supplies of the metal.

Tesla, one of the leading EV producers in the world, is reported to have been in talks to go one more step and purchase 10 to 20 percent of a mining company, Swiss commodities group Glencore.

Ford has a lithium offtake agreement with Australia-based Lontown Resources that includes stumping up financing for the project upfront, and has taken a minority stake in a nickel ore processing plant in Indonesia. ■



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EU to introduce Critical Raw Materials Act; Europeans want to bolster domestic production of critical minerals

THE EUROPEAN Union is set to unveil its Critical Raw Materials Act this month, and Commissioner Thierry Breton is looking for more funding from financiers for suppliers of minerals needed for the energy transition.

Reuters reported that Breton told a roundtable of European banks including Société Générale, Deutsche Bank and Santander Group that the EU must secure the bloc's supply of critical raw materials including lithium, cobalt, nickel, manganese and graphite needed for electric vehicles.

He highlighted two major issues. The first is overreliance on countries such as major producer China for materials such as magnesium used in electronics, cars and machinery. The second is the expected "colossal" increase in demand.

The EU's dependency has become a critical issue following soaring energy prices that have resulted from Russia's invasion of Ukraine.

"I want you to invest in operations in the critical raw materials value chain," Breton told the roundtable, according to a transcript of his remarks seen by *Reuters*.

"Sometimes you faced challenges: here in Europe, because of local opposition, long procedures or lack of economic case; or in the rest of the world, where you may be accused of supporting projects with low environmental and social standards," he added, addressing the room at Brussels' Berlaymont hotel.

Having to coordinate legislation across 27 members, the bloc is lagging other Western countries, such as the United States and Canada, which have already introduced bills to secure clean energy and energy transition materials.

The head of the European Commission, Ursula von der Leyen, said last week the EU was making available a European Sovereignty Fund to keep firms from moving to the United States.

According to a report from Bloomberg, Eurometaux — which represents major European producers

including Glencore Plc, Boliden AB, and Aurubis AG — urged the EU to take inspiration from President Joe Biden's Inflation Reduction Act, which includes billions of dollars of subsidies to spur domestic investment in electric vehicles and renewable energy.

EU leaders are set to meet in Brussels next month to discuss a response to the controversial U.S. act, with some pushing for a "made in Europe" approach to help bolster domestic companies. French President Emmanuel Macron called for an EU package amounting to 2 percent of its economic output to rival the \$370 billion U.S. plan.

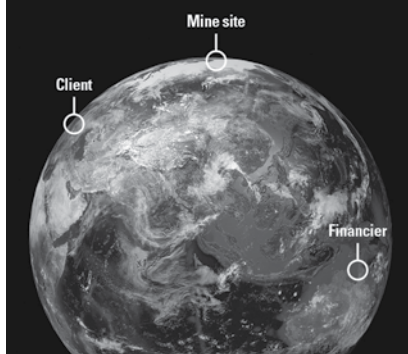
"The U.S. Inflation Reduction Act, while discriminatory, has shown what a proactive clean-tech industrial policy could look like," Evangelos Mytilineos, president of Eurometaux and chief executive officer of Greek aluminum company Mytilineos, said in a letter to the European Commission. "We in Europe should be inspired by its example, and deliver more carrot and less stick to our industries, especially in today's energy crisis." ■

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Workforce: Investment needed to recruit and retain talent

(continued from page 6)

based company.

To help retain its workforce, Adkerson said Freeport plans to give "substantial" pay raises to its U.S. staff this year. The company is working to train replacement workers, but added that the experience level of its staff in the United States is not what it was even five years ago.

"I think that does have some implications on our ability to develop a mine in the U.S.," Quirk said. More than half of Freeport's estimated 235 billion pounds of copper resources are in the United States, and Adkerson has called the country key to Freeport's growth plans.

Freeport posted fourth-quarter net income of \$697 million, or 48 cents

per share, compared with \$1.1 billion, or 74 cents per share, in the year-ago period. Excluding one-time items, Freeport posted a quarterly profit of 52 cents per share, ahead of analysts' estimate of 46 cents per share, according to Refinitiv data.

Freeport reported average realized copper prices of \$3.77 per pound in the quarter, compared with \$4.42 a year earlier. The company expects its annual capital expenditure to be about \$5.2 billion, higher than \$3.5 billion marked in 2022.

Despite recent macroeconomic concerns, especially in China, Freeport said it has not seen slowing demand for the red metal. "If we could produce more, our customers would want it," Quirk said. ■

EPA issues determination to block Pebble Mine; Clean Water Act bans disposal of mine waste

THE U.S. Environmental Protection Agency (EPA) took steps to block the Pebble Mine in Alaska.

The *Associated Press* reported that the EPA issued a final determination under the Clean Water Act that bans the disposal of mine waste in part of the bay's watershed, about 322 km (200 miles) southwest of Anchorage. Streams in the watershed are crucial breeding grounds for salmon, but the area also contains deposits of precious-metal ores thought to be worth several hundred billion dollars.

"This preemptive action against Pebble is not supported legally, technically or environmentally," said John Shively, chief executive of Pebble LP, which is owned by Canada-based Northern Dynasty Minerals Ltd.

He also said President Joe Biden's strategy to secure minerals

for green energy goals seems to be giving "passing support" to minerals such as lithium in the United States and seeking an "enormous supply of copper ... from other nations."

The Pebble deposit is near the headwaters of the Bristol Bay watershed, which supports a bounty of salmon "unrivaled anywhere in North America," according to the EPA.

The announcement marks only the 14th time in the roughly 50-year history of the federal Clean Water Act that the EPA has flexed its powers to bar or restrict activities over their potential impact on waters, including fisheries. EPA administrator Michael Regan said his agency's use of its so-called veto authority in this case "underscores the true irreplaceable and invaluable natural wonder that is Bristol Bay."

The EPA, citing an analysis by the Army Corps of Engineers, said discharges of dredged or fill material to build and operate the proposed mine site would result in a loss of about 100 miles (160 km) of stream habitat, as well as wetlands.

Pebble LP has maintained that the project can coexist with salmon. The partnership's website says the deposit is at the upper reaches of three "very small tributaries" and expresses confidence any impacts on the fishery "in the unlikely event of an incident" would be "minimal."

Republican Alaska Gov. Mike Dunleavy said the EPA's veto was a dangerous precedent that could affect future development in the state, while state Attorney General Treg Taylor called the agency's action "legally indefensible." ■

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Marc LeVier; An interview with the 2023 SME President

by William Gleason, Editor



Marc LeVier became the 2023 SME President on March 1, 2023 at the conclusion of the MINEXCHANGE 2023 SME Annual Conference & Expo in Denver, CO. LeVier, a 53-year member of the Society, spent the majority of his career with Newmont as senior director of metallurgical research and development, where he played an integral role in rebuilding the Newmont research and development (R&D) team. The R&D team was responsible for leading Newmont Gold Company's development of

gold mines in Nevada. The mine-development successes came at a critical time in Newmont's history and allowed Newmont to rebuild internationally to Newmont Mining Corporation.

Before he made his mark with Newmont, LeVier served in the U.S. Army Corps of Engineers, and worked for a variety of other companies. Following his retirement from Newmont, he ventured into the rare earth sector, serving as chief executive officer and president of Texas Rare Earth Resources and Great Western Minerals Group. He is currently president of K. Marc LeVier & Associates, Inc.

LeVier is a proud graduate of Michigan Technological University (Michigan Tech) where he earned a bachelor of science degree in metallurgical engineering in 1971, followed by four years in the U.S. Army Corps of Engineers. After his time in the service, LeVier earned a master's degree in metallurgical engineering from Michigan Tech. He has used his education, as well as lessons learned in the military, throughout a career in which he developed a well-earned reputation as a successful leader and team builder.

From his early days as a student at Michigan Tech to today, SME has been an influential part of his journey. LeVier recently spoke with *Mining Engineering* about his life, career, the mining industry and his goals for his term as President of SME.

Foundation

LeVier was born in the New Bethlehem area of Pennsylvania, north of Pittsburgh, in a time when coal mining supported the majority of the local population, including LeVier's family. At just two-and-a-half years old, LeVier's biological father was killed in an industrial accident while working as an equipment operator at a brick company that produced brick and tile from fire clay mined in the area. The accident that took LeVier's father was likely the result of poor safety standards at the plant, and one that shaped LeVier's personal and professional life.

Among his areas of focus for his term as SME President is the elevation of SME's Health & Safety Division.

"The Health & Safety Division is our newest division, but it is a great one," LeVier

said from his home in Highlands Ranch, CO. "I want to learn about their programming and what they are doing and how do we get more people involved. For example, how do we get the corporate safety people involved? How do we get the operations safety personnel and MSHA involved with the Division?"

"Not only is health and safety the top value for all of us, safety also contributes to the bottom line because these are things that can shut down production. And beyond that, I can tell you, if you are the person who has to tell someone that their loved one is not coming home, it is one of the hardest things you will ever have to do," said LeVier.

In 2017, LeVier was awarded the St. Barbara's Day Award by the Colorado Mining Association for his efforts in the area of mine safety and health. St. Barbara is the patron saint of miners, military engineers, artillery personnel and others who work with explosives. For a man who has collected numerous professional awards including two SME Presidential Citations, SME Distinguished Member, Montana State Board of Regents Honorary Doctor of Science, SME Ivan B. Rahn Award, MEC Outstanding

Individual Award and Colorado MPD Arthur C. Daman Lifetime Achievement Award, it is telling that this is one of the awards that stands out most for LeVier.

"I was two-and-a-half years old when my father died and I still remember. I remember him as a loving father and I remember the impact on my family when he was killed, heart break, grieving. I know the impact that it made on my life. I was blessed that I had a stepfather that loved me and took care of me, but that tragic incident is why the award was so special to me," said LeVier. "When I think about continuous improvement, I think about safety. We need to continue to improve that Division and make it world class."

As a young man, LeVier was aware of the importance of coal mining and had an interest in the metallurgical processing used in steelmaking in the Pittsburgh area, but he did not aspire to a career in the mining industry. His first intention was to pursue physical metallurgy in the Pittsburgh area, or to become a teacher.

While exploring vocational catalogues, a photo in Michigan Tech's publication showed a student in waist-deep snow holding a white-

A mining career spanning work in the United States, Canada and abroad

Here is a peek at just some of Marc LeVier's vast career experiences in the mining world.

Today, LeVier is an accomplished senior-level executive who has led a number of natural-resource organizations. He is a multidimensional leader with extensive international experience and is recognized as a leader in mineral processing research and development. He is an independent and innovative thinker with excellent communication, interpersonal and problem-solving skills.

LeVier has been involved in all facets of the mining industry including work in process improvement, team building and cultural change, technology and innovation implementation, strategic and operations planning, investor relations, financial strategy, environmental and social responsibility and industrial health

and safety.

Much of LeVier's career was spent at Newmont Mining Corp., where he worked from 1989 to 2011 in a variety of increasingly demanding positions including as global director of metallurgical research and development.

In more recent years, LeVier's professional experiences include work as president, chief executive officer and director with Great Western Minerals Group (GWMG) Ltd in Saskatoon, Saskatchewan, which is a Canadian junior mining company and a manufacturer of specialty metals and metal alloys based on rare earth elements at a United Kingdom-based facility. GWMG is developing a high-grade rare earth element mineral property in the Western Cape Province of South Africa.

LeVier also was formerly president, chief executive officer and director at Texas Rare Earth

Resources (TRER) in Sierra Blanca, TX. A U.S. start-up mineral exploration company, TRER owns mineral rights to Round Top Mountain near Sierra Blanca that is attempting to develop the property to produce uranium, beryllium, rare earths and lithium.

In the early part of his career, LeVier worked at Derrick Manufacturing Corp., Joy Manufacturing Corp., and also at Exxon Minerals Co. His educational achievements include earning bachelor's and master's degrees in metallurgical engineering from Michigan Technological University, as well as an honorary doctor of science degree from the University of Montana.

He is a professional member of the Society for Mining, Metallurgy & Exploration (SME); Mining and Metallurgical Society of America (MMSA) and Canadian Institute of Mining and Metallurgy (CIM). ■

tail deer that caught the attention of a young LeVier, who was an avid hunter, and still is. That catalogue, along with sound advice from a family friend about the reputation of the school's metallurgical engineering program had him hooked, and LeVier was soon headed west to Michigan.

In a career that would later be heavily influenced by the connections he has made along the way, one of the most important connections in LeVier's life came when he asked for help from Dr. Lloyd Heldt with a required class that he was struggling with.

"There are no coincidences in life," LeVier said of the meeting with the professor. "Things happen for a reason, and it's so true in many aspects of my career and life in general."

LeVier became close to Heldt and in the spring of his sophomore year he took a class on the Fundamentals of Mineral Processing from Prof. Frank Chernosky that included a field trip to the Ispheming's Empire Mine in the Marquette iron ore range.

"We did a complete tour of the whole operation that included the full mining cycle," LeVier said. "When I saw that haul truck come up with the big slabs of iron ore, and it dropped those rocks in the gyratory crusher, and I saw that crusher eat that piece of rock, it was one of the most impressive things I'd seen."

The group followed the ore through the plant where they saw the grinding and selective flotation to make the iron ore concentrate, and through the thickening, filtration and drying process, and eventually it was shipped out as iron ore pellets. The next time LeVier saw Chernosky, he committed to mineral processing as a major. Chernosky would continue as his advisor and push him to the limit. (Things happen for a reason.)

As a student at Michigan Tech, LeVier joined the Reserve Officers' Training Corps program, in part because it was another group to join, and in part because he earned a scholarship. Following graduation, he attended the Army's Engineer Officer Basic Course in Fort Belvoir, VA. After graduation on Dec. 20, 1971, he landed in Frankfurt, Germany for his first duty assignment. He traveled to the 78th Engineer Battalion (Combat) in the city of Karlsruhe, where he learned hands-on problem-solving while building bridges, doing road construction, and tactical support as well as leadership skills that would serve him well throughout his career.

During a trip home, he paid a visit to Michigan Tech where his former professor,

Heldt, talked him into returning to the university to pursue his master's degree.

As his career progressed, he embraced the opportunity to engage with the generations of engineers who have followed. As a senior member at Newmont he was influential in providing funds for many colleges including Montana Tech, the University of Utah and the South Dakota School of Mines and Technology.

As President of SME, he will maintain a focus on keeping the relationships between SME and academia strong.

"I want to understand: What are the needs of the schools and how can SME help them, especially in the recruitment of students?" said LeVier.

He cited the Jobs of Tomorrow program and the proposed Mineral Schools Grant Bill that is before the U.S. Congress as positive advancements. "The Mineral Schools Grant Bill would make a huge difference for our schools, and it will require some involvement from SME," he said.

He will also work to bridge the gap between experienced members and those new to the Society.

"We have a Grand Canyon-sized chasm in our membership between Baby Boomers and Gen Z," LeVier said. "We have to be responsible to our senior members who have done so much for the Society and the industry, while also creating a Society that is engaging for the newest members."

Career

Following work at Exxon Minerals Co., Joy Manufacturing Corp. and Derrick Manufacturing Corp. that included moves around the United States, LeVier eventually landed at Newmont in a time when the company was in a state of flux. At the time it was moving its headquarters from New York to Denver, CO, while the R&D team landed in Salt Lake City in the University of Utah's Research Park, having been in Danbury, CT since its inception in 1956.

Throughout his career, connections made through SME played a significant role. Richard Bullock, Legion of Honor member and National Mining Hall of Fame member, hired LeVier to Exxon and another Legion of Honor and Hall of Fame member, Len Harris, was influential in recruiting LeVier to Newmont after the two connected at an SME conference.

LeVier joined Newmont on March 1, 1989, where he managed the minerals processing

team while the company was developing a refractory gold ore process. It was a role that he compared to being the conductor of an orchestra — when the individual instruments are warming up it might sound chaotic and messy, but when the instruments are organized to work together, the result is beautiful music.

“We had a great team of highly skilled individuals, and it was my job to get them to work together,” he said.

Working with a world-class team, LeVier oversaw the process development of the Gold Quarry refractory ore testing, which resulted in the Refractory Ore Treatment Plant (ROTP) at the Carlin Trend in Nevada.

“We not only had to prove a process, but we had to disprove other processes to convince the Newmont board that it was the correct way to go,” LeVier said. “We ultimately ended up with a roaster. It was a breakthrough technology of roasting whole ore with enriched oxygen, which reacted the arsenic content to a stable product in the calcine and not to the hot off-gases.”

He also worked on the development of the Batu Hijau porphyry copper-gold mine in Indonesia, the heap leach operations at Minera Yanacocha in Peru, the Ahafo operations in Ghana, the Phoenix operation in Nevada, and the Boddington operation in Australia. Additionally, he led teams in the development of the former operations at Minahasa in Indonesia and the Zarafshan-Newmont joint-venture heap leach operation in Uzbekistan.

His contributions are further acknowledged in the process patents that were granted to Newmont in the areas of bio-oxidation, whole ore roasting, and pressure oxidation of gold ores. He guided the Newmont teams in research in the use of alternative lixiviants, such as thiosulfate, thiocyanate and thiourea in the leaching of gold ores. The Newmont metallurgical team also led the industry in the development and use of membrane technology in the treatment of process solutions, along with other proprietary water treatment methods to allow responsible discharge of solutions to the environment.

“It was basically letting people do their jobs,” LeVier said. “It was about listening to everyone’s ideas. If a mineralogist had a question about the metallurgy, we wanted to hear it.”

“We really had a fantastic team, including Arnie McGuire, Dave Hill, Jim Brierley, Corale Brierley, Brian Ball, Sevket Acar,

Rong Yu Wan, Rene Fernandez and Gopalan Ramadorai. We also had a world-class mineralogy group including Don Hausen, John Ahlrichs, Jerry Odekirk, Mark McComb and Louis DeVries. I was very fortunate to have a great team of people, and my job was to make them play well together, and frankly, it wasn’t that hard. It was about making everyone feel like they were part of a team. I had to maintain the bigger picture. Running the lab was making sure my people had what they needed. We were a team but more importantly, we became family and supported each other in many ways. Much like SME, my colleagues have become my best friends and we are all part of a great family.

“Of course all of this would not have been possible without excellent executive leadership from Gordon Parker and Peter Phillip. The operations VPs, Ken Brunk, Walt Lawrence and Eric Hamer, were always challenging us and pushing us. It felt more like torture sometimes but it was all character building. The years in the military allowed me to balance all of the ideas and comments while the R&D team drove strategic objectives that produced results. That R&D team of engineers, chemists and technicians were the real heroes alongside the project engineers and excellent operations folks in Nevada. #NeverQuit,” said LeVier.

There are so many people who supported me and the team continued to grow to even greater heights over the years with growth of new-hire personnel and personnel from acquisitions, like Gary Simmons and Rob Dunne.

Following his time with Newmont, LeVier worked as a consultant, and in the rare earth element sector, where he was president and chief executive officer, and director of Great Western Minerals Group from 2013 to 2015, and was chief executive officer, president and director of Texas Rare Earth Resources (TMRC now) before that.

Mining industry outlook

“These are interesting times. We have this huge potential out there with the critical minerals and production needs, driven by “green” energy demands,” LeVier said. “However, I am a firm believer that you should have a lot of tools in your tool box, and that fossil fuels still play a huge role in the energy picture. When it comes to the energy transition we need to figure out: what is a good transition? What is a good strategic plan to get to a carbon-neutral economy? There are a lot

of issues to be resolved, and there needs to be a strategy of integration to implement change. That's what we do every day in our industry when we plan new mines and implement mine plans. When the mining industry has been challenged, the industry innovates and succeeds. I have never seen them fail. It is a unique and exciting community."

With more than 50 years of experience in the mining industry, LeVier will bring a broad perspective to his role as SME President. Among the challenges facing the mining industry, he cited are financing for new projects, permitting issues and human resource development.

"It is difficult to raise money as a junior or at a company that is doing exploration, and these are the people we need to increase the lithium and rare earth potential," said LeVier. "For example, everything we have produced since the start of the industrial age in terms of copper we need to produce again between now and 2050. A key to this is going to be permitting and streamlining permitting. We have to have a consistent process for permitting so that we can permit and mine. U.S. production of critical minerals and materials is a must for our future. Failure is not an option."

"The state of the industry is good, but it is going to be trying times in terms of finance. Inflation is a concern, and there are some huge goals that need to be addressed. I think SME is going to play a role in that, because SME is where the experts are."

Resources

In addition to finding resources in the ground, the industry is challenged with finding the people to carry it forward. "Where are the human resources going to come from? Beginning with Bill Edgerton as SME President, the SME Board has devoted much time and resources to highlighting the value of mining to the general public. We are good at talking to ourselves, but we really need to turn outward in the next few years to educate

people about mining and minerals and their effects on our daily lives," said LeVier. "SME efforts with "Jobs of Tomorrow" and other initiatives are going to help, but it's about getting the information out to young people about the careers they can have in our industry. It's about letting them know that it's more than geology and mining and metallurgy. We need environmental and bio sciences, and mechanical and computer engineers. We need the best and the brightest, and people who want to think outside of the box and who are innovative. We need to figure out how to attract those people. We need to look around and take the blinders off, the people are there. I am a big advocate of men and women coming out of the military service. They have lots of skills, hands-on talent, dedication, a strong work ethic and great trade and craft skills, real leaders."

As President of SME, LeVier will work to support all of the Society's strategic committees and divisions, and he cited a special interest in SME's Coal & Energy Division too.

"I want to hear what they are doing," he said. "There is a lot of talk about eliminating fossil fuels and creating a "green" economy, but coal is still needed. This year, there were record volumes of coal exported and record revenues. There is more innovative research in coal today than any time in my career and most is going unnoticed. We need to change that. I want to understand the Coal & Energy Division's needs, and to continue to support that Division."

"And I want to focus on innovation across all divisions. We need the Innovation Strategic Committee to talk with each division and find opportunities that will attract young engineers to our industry to create the next generation of innovative solutions," LeVier said.

When asked if he had any final thoughts on the year ahead LeVier replied, "Everything happens for a reason, there are no coincidences. I look forward to 2023 with SME." ■



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Extraction of critical electronic materials from steelmaking wastes

by Weston Hartzell and Michael Moats

The stable domestic supply of gallium (Ga), indium (In) and germanium (Ge) has been identified as a critical need for the United States. Electric arc furnace (EAF) dusts processed to recover zinc produce a process residue that could be a potential source of these critical materials. For this study, an industrial zinc leach residue was characterized to determine the predominant mineral phases and leached with common mineral acids. Atmospheric agitated leaching using sulfuric acid and hydrochloric acid were examined to determine the extractions of gallium, indium and germanium as a function of concentration and temperature. Extractions of gallium were found to be similar to iron in all experiments. The maximum percentage of gallium, indium and germanium leached into solution were 71 percent, 63 percent and 48 percent, respectively.

The United States currently has no primary production for gallium, indium and germanium with the gallium supply being of greatest concern (USGS, 2022; Nassar et al., 2021). Compounding the lack of domestic production of these elements is the availability of these by-product elements because of geopolitical concerns. The wide array of applications and limited replaceability couple to place these elements on the United States critical minerals list with gallium listed as the number one at-risk mineral (USGS, 2022).

Gallium is a post-transition metal that is heavily used in electronics and photovoltaics. It is used in semiconductors, light-emitting diodes (LEDs), solar arrays, power electronics for radio-frequency transmission equipment and low-melting-temperature alloys (Lu et al., 2017; Licht et al., 2015; Frenzel et al., 2016; Foley et al., 2017). Though there is broad use for gallium, it is limited in availability. Lack of primary deposit formation, low concentrations with other minerals and relatively low prices result in the collection of gallium as a by-product. Gallium is mostly recovered from the processing of bauxite ores but can also be extracted from zinc processing residues and coal fly ash (Lu et al., 2017; Licht et al., 2015; Frenzel et al., 2016; Foley et al., 2017). Extraction of gallium from these sources involves leaching, which may require elevated pressure and temperature and precipitation and/or filtration; except in the processing of Bayer liquor where solvent extraction, ion exchange and electrochemical

deposition are used (Lu et al., 2017).

Germanium is a metalloid also heavily used in electronic and optical components. Uses include fiber optics, infrared optics, catalytic component in the production of polyethylene terephthalate, LEDs and semiconductor electronics and solar-cell applications for orbital assets (Licht et al., 2015; Foley et al., 2017). Available resources for germanium are more limited than those of gallium. Primary recovery is as a by-product of zinc production with limited production from coal fly ash and silver, lead and copper ores (Licht et al., 2015; Foley et al., 2017).

Indium is another post-transition metal used in a variety of electronics and optics. Indium is commonly used in flat-panel displays, touch screens, LEDs, laser diodes, solar cells, solders and as an alloying component (Licht et al., 2015; USGS, 2017). Indium is only producible as a by-product of zinc production (Licht et al. 2015; Foley et al., 2017).

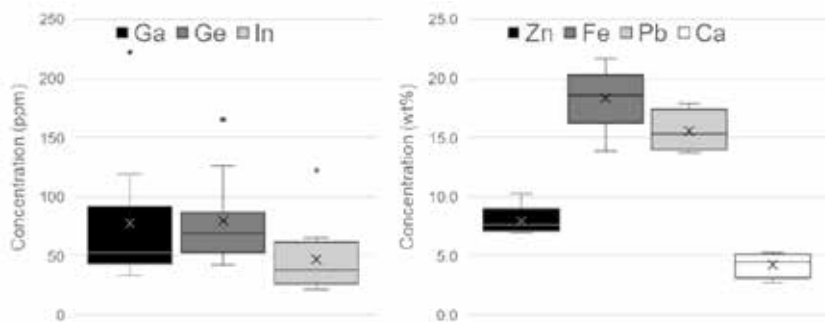
Previous research on the extraction of gallium, germanium and indium has focused on currently utilized sources. A common source for gallium, germanium and indium is the leach residue from zinc processing. Different lixiviants, multiple leach stages and reducing agents have been examined.

Sulfuric acid (H_2SO_4) is the dominant lixiviant used in leaching zinc residues. Zhu et al. (2021) leached secondary zinc oxide using spent zinc electrowinning electrolyte to extract zinc as well as 90 percent of the germanium in a batch process and 88 percent in a continuous leach.

Multistage leaching has been examined to extract selected elements using different lixiviants or as an enriching process prior to targeting selected elements. Fupeng et al. (2017) conducted a two-stage leach of zinc refinery residues using sulfuric acid to remove zinc and copper in the first stage. A second leach using oxalic acid extracted 96 percent and 99 percent of the gallium and germanium, respectively. Rao et al. (2019) conducted a two-stage leach of zinc refinery residues using H_2SO_4 to extract zinc and approximately 100 percent of the gallium in the first stage. A second leach used sodium hydroxide (NaOH) and extracted 90 percent of the germanium along with lead

Weston Hartzell is a graduate research assistant studying metallurgical engineering at Missouri University of Science and Technology (Missouri S&T) and Michael Moats is professor and chair, Materials Science and Engineering, Missouri S&T. Email: moatsm@mst.edu or wchwcx@mts.edu.

Figure 1
Selected elemental compositions of zinc leach residue.



(Pb). Rao et al. (2021) conducted a three-stage leach of zinc refinery residues using H_2SO_4 to extract zinc and gallium (99 percent) in the first stage. A second leach, using hydrochloric acid (HCl), extracted approximately 99 percent of the lead, and a third leach, using NaOH, extracted 90 percent germanium.

Reductive processes in leaching have been used to reduce iron in the leaching process. Wu et al. (2012) examined the addition of sulfur dioxide to a sulfuric acid pressure leach of zinc residue, which extracted 91 percent gallium. Zhang et al. (2016) examined the addition of sphalerite during two-stage leaching of a zinc neutral-leach residue. Zinc and 97 percent indium were extracted from the final stage. Kashyap et al. (2021) examined reductive roasting of zinc refinery residue prior to leaching. Sulfuric acid leach extracted 96 percent indium, 41 percent gallium, and zinc.

A potential domestic source of gallium, germanium and indium is EAF dust. EAF dust has many hazardous constituents and is already captured and treated as required by the U.S. Environmental Protection Agency (EPA) regulations (EPA, 1975). EAF dust processed through Waelz kilns produce crude zinc oxide (CZO) that is a feed source for zinc production (Cusano et al., 2017). CZO has been shown to have a complex composition of metallic components (Wang et al., 2021; Cusano et al., 2017; Ding et al., 2015). Our research has identified that domestic CZO contains tens of ppms of gallium, germanium and indium. Given the large volume of EAF dust treated in the United States, this could be a valuable source of the elements. This research examined a zinc leach residue which was exclusively produced from EAF-dust CZO. The goals were to physically characterize the residue and determine if gallium, germanium and indium could be extracted by mineral acids into an aqueous phase.

Experimental

Thirty kilograms of wet leach residue were obtained from a zinc refinery located in the United States. This material was dried, divided, characterized and leached.

Sample drying. Sample drying was accomplished by spreading a layer of the residue on stainless steel trays with a maximum thickness of 15 mm. The residue was dried in a BVV Neocision ETL vacuum oven for five days at 40 °C under 700 mmHG vacuum. These conditions were selected to avoid mineral decomposition by excess heating.

Sample division. Dried residue was screened using a ROTAP RX-29 sieve shaker until all material passed a 9.5-mm screen. Material was then transferred to a Gilson SP-245 rotary splitter to create eight initial samples. The initial samples were split a second time resulting in 64 representative random samples.

Sample preparation. Sample selection was randomized from the 64 splits. The randomly selected samples were sieved by hand and deagglomerated using mortar and pestle until 90 percent passing #25 (710 μ m) mesh was achieved. Cone and quartering was used to reduce the sample size to around 100 g for use in leaching.

Particle size analysis. Approximately 0.7 g from four residue samples was added to 20 mL of greater than 99.9 percent isopropyl alcohol and placed in an ultrasonic bath for 10 minutes to disperse the solids. Samples were removed from the ultrasonic bath, shaken for 10 seconds and checked visually for clumping. Each specimen was analyzed using a NanoTrac 250 laser-diffraction particle size analyzer in conjunction with MicroTrac Flex software. The process was repeated three times, and results were averaged. The particle size measurements were confirmed using a scanning electron microscope.

Inductively coupled plasma (ICP). The chemical composition of solids (after fusion) and liquids were determined using a PerkinElmer NexION 300X ICP-MS inductively coupled plasma mass spectrometer operated in kinetic energy discrimination mode. Gallium and germanium signals were corrected for double-charged ions of barium (Ba), cerium (Ce) and neodymium (Nd) as well as for the remaining 56-FeO polyatomic for 72-Ge only. Indium signals were corrected for 115-Sn using measured 115/118 Sn signal ratios. The ICP-MS was calibrated using a four-standard series, each with its own mixture of elements, prepared from commercial high-purity standards multi- and single-element stock solutions.

X-ray diffraction (XRD). Residue samples

Table 1

Particle size distribution of zinc leach residue.

Sample	D ₁₀ (μm)	D ₅₀ (μm)	D ₉₀ (μm)
1	1.6	3.2	4.6
2	1.4	2.3	3.2
3	1.5	2.5	4.3

were randomly selected and analyzed using a Philips PANalytical X'Per multipurpose diffractometer with a copper (Cu) source operated at 45 kV and 40 mA. The 2θ angle was measured from 5° to 90° over 30 minutes, resulting in an approximately 3°/min measurement rate. Upon completion of initial XRD evaluation, samples were ground to smaller than 200#. Titanium dioxide (TiO₂) was added to the samples to refine the XRD results via Rietveld analysis. This provided additional accuracy for the weight percent of each phase and determination of amorphous materials.

SEM/EDS. Approximately 1 g of residue was pelletized, mounted to a scanning electron microscope (SEM) stub mount with carbon paste and lightly sputter-coated with carbon. SEM imaging and energy-dispersive X-ray spectroscopy (EDS) was conducted on a PrismaE variable-pressure SEM with an accelerating voltage of 20 keV and magnification of 2,000x to 5,000x. Pressure was varied to reduce the static charge buildup on the surface of the sample. Area and point EDS scans were conducted at two randomly selected locations for each sample.

Leaching. Leaching was conducted in a 1-L glass, round-bottom, jacketed reaction vessel with a 100-mm inner diameter. A 38-mm flat-paddle agitator was positioned at one-third the height of the vessel from the bottom with a 38-mm turbine agitator mounted at two-thirds the height of the vessel. Conditions of the leach were 1 L of acid, liquid/solid ratio of 10, agitator speed of 400 rpm, time of six hours, temperature of 50, 70 and 90 °C, and 1.17 M and 6.99 M HCl or 0.82 M, 1.63 M and 3.27 M H₂SO₄. A full factorial design without replicates was used and randomized.

Results and discussion

The leach residue was physically characterized to determine particle size, chemical composition, mineralogy and elemental deportment.

Particle size analysis. The residue

was determined to be fine particulates with the majority between 1 and 5 μm in size. Particle size distribution measurements are summarized in Table 1.

Chemical composition. The industrial residue contained high concentrations (5 to 20 weight percent) of zinc (Zn), iron (Fe), lead (Pb) and calcium (Ca), which was expected considering the process in which it was produced. Concentrations of gallium, germanium and indium averaged between 50 and 75 ppm. Figure 1 shows the ranges and averages of concentrations measured for these seven elements.

Analysis of individual sample results revealed that the concentrations of gallium, germanium and indium were positively correlated with increasing iron concentration and decreasing calcium.

XRD. Since gallium, germanium and indium concentrations correlate with iron concentrations in the residues, XRD was employed to determine the iron-bearing phases. The XRD spectra from Rietveld analysis of



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Figure 2

XRD patterns of three residue samples.

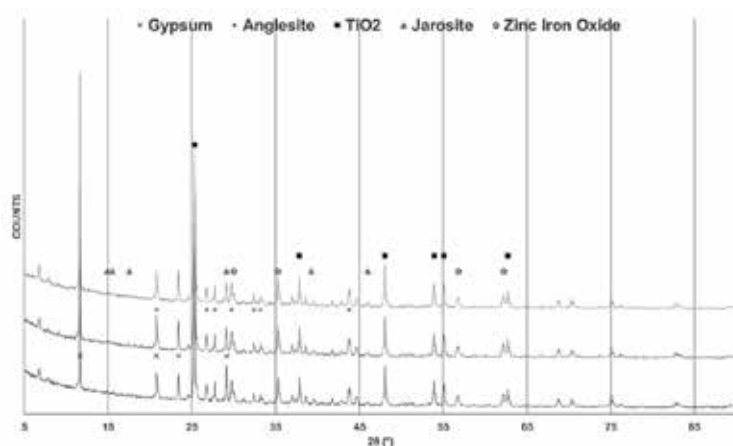


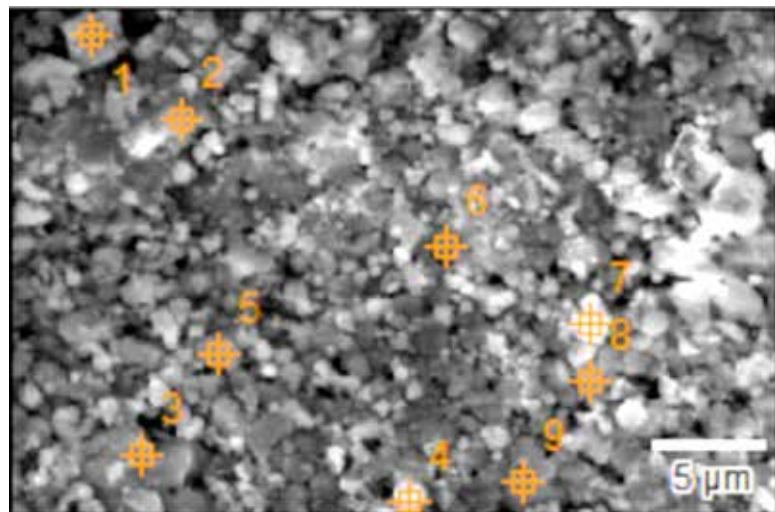
Table 2

Rietveld analysis determination of phases in three residue samples.

Sample	Angle-site (wt percent)	Zinc iron oxide (wt percent)	Calcium sulfate dihydrate (wt percent)	Jarosite (wt percent)	Amorphous (wt percent)
1	12	17	36	8	27
2	12	21	38	8	21
3	12	19	38	7	24

Figure 3

Scanning electron microscope image with point scan locations of residue sample.



three residue samples are shown in Fig. 2. Four major crystalline phases were found: anglesite $[Pb(SO_4)]$, zinc iron oxide $[ZnFe_2O_4]$, calcium sulfate hydrate (gypsum) $[CaSO_4 \cdot (H_2O)_{0.5}]$ and jarosite $[K(Fe_3(SO_4)_2(OH)_6)]$. Jarosite and calcium sulfate hydrate share many of the same peaks; however, the asymmetry of the peak at

circa 29° and peaks at 39° and 46° indicate a combination of both phases.

The computed compositions of the phases determined by Rietveld analysis of three samples are provided in Table 2. The most prevalent phase was gypsum. Results showed 21 to 27 percent of the residue was amorphous in nature. Zinc iron oxide was the most abundant iron-bearing crystalline phase.

Since jarosite compounds were present, a sample was separated using a handheld magnet. A split of roughly 75 percent and 25 percent was found to be magnetic and nonmagnetic, respectively. XRD analysis of the magnetic and nonmagnetic portions of the sample did not indicate significant differences in phase composition. Upgrading by magnetic separation was not explored further but may be worth future investigation.

SEM-EDS. Area scans of residue samples (Fig. 3 shows a sample SEM image) did not indicate that mineral phases are isolated to individual particles. There are indications that some particles are more concentrated in one element as opposed to others, as evidenced by the presence of sulfur and lead with the absences of iron and zinc. No elevated concentrations of gallium, germanium and indium were found using SEM-EDS. Based on the EDS area scans and particle size/feature, point locations were chosen as indicated in Fig. 3. As many of the particles approach the size of the electron beam, large particles were selected for analysis.

Table 3 shows the composition of the EDS scans at each point by elemental weight percent. The EDS measurements appear to confirm the ICP and XRD analyses in terms of compositions and likely phases. Measurements were conducted without standard, therefore readings below 1 percent were considered not reliable.

Leaching. Atmospheric agitated leaching was performed using heated H_2SO_4 and HCl for six hours. Extraction rates were calculated using head-grade concentration information provided by the industrial partner and leachate concentrations. Figures 4 to 6 show the extraction rates for selected elements in H_2SO_4 and HCl. Sulfuric and hydrochloric acid leaching produced similar trends with the exception that HCl leaching extracted lead and calcium into the leachate. Except for 0.82 M H_2SO_4 , the trials showed consistent trends of increasing extraction percentages with increasing temperature over the range of 50 to $90^\circ C$.

The extraction trends of gallium, indium

Table 3

Weight percents by energy-dispersive X-ray spectroscopy point analysis of residue sample (N.D. = not detected).

Point	O	Si	S	K	Ca	Mn	Fe	Zn	Pb
1	37.3	<1.0	2.6	<1.0	<1.0	3.7	36.6	12.8	4.8
2	43.9	1.0	13.7	1.5	8.3	2.1	23.1	6.1	N.D.
3	49.9	<1.0	10.5	3.6	2.6	1.5	26.2	5.0	N.D.
4	44.4	1.3	7.2	1.4	1.0	2.8	29.6	12.0	N.D.
5	50.2	<1.0	12.5	3.9	1.4	1.1	25.2	4.2	N.D.
6	41.4	1.0	8.7	2.7	1.7	1.3	26.9	5.1	11.2
7	41.0	<1.0	7.0	1.2	1.2	<1.0	11.1	3.0	29.7
8	35.6	1.0	13.5	3.2	1.4	2.5	34.1	8.3	N.D.
9	49.5	<1.0	10.6	1.4	5.4	1.4	22.3	5.0	N.D.

and iron were similar. This again indicates that gallium and indium are associated with iron within the residue as expected from previous chemical composition analysis. The higher zinc extraction values relative to iron may indicate that the zinc iron oxide phase is dissolving more than the jarosite phase. If jarosite is not dissolving adequately, this may be hindering higher extractions of gallium, germanium and indium. Characterization of the solids remaining after leaching are underway and should resolve this uncertainty.

Gallium extraction ranged from 51 to 82 percent. Increasing H_2SO_4 concentration from 0.82 M to 1.63 M or 3.27 M led to higher gallium extraction. Using 1.17 M or 6.99 M HCl did not increase the extraction of gallium relative to 1.63 M or 3.27 M H_2SO_4 . The highest gallium extraction was achieved with 1.63 M H_2SO_4 at 90 °C.

Germanium extraction decreased with increasing acidity in both H_2SO_4 and HCl. Extraction ranged from 76 to approximately 100 percent. The highest extraction occurred using 0.82 M H_2SO_4 at 70 °C.

Indium extraction followed a similar trend to that of gallium, indicating that it also likely coprecipitated in the same phases as gallium. Indium extraction ranged from 61 to 89 percent. The highest extraction was achieved with 1.63 M H_2SO_4 at 90 °C.

Analysis of the leaching results indicates

that utilization of 1.63 M H_2SO_4 at 70 or 90 °C appears to be the most favorable. These conditions produce high extractions of zinc, gallium, germanium and indium, avoid costly materials of construction necessary to employ HCl leaching, and produces a residue that is enriched in lead which could be sent to a lead smelter as feed material. The recovery of gallium, germanium and indium from H_2SO_4 solutions containing iron and zinc is the focus of an ongoing investigation and will be reported in the future.

Conclusions

Gallium, indium and germanium are necessary for the continued expansion and development of green power generation, consumer electronics and military hardware. Zinc residues produced from the recycling of EAF dusts could be sources for these elements. A domestic zinc leach residue produced from EAF dusts was physically characterized and leached with mineral acids. The residue consisted mostly of particles with size of 1 to 5 μm and contained 50 to 75 ppm indium, germanium and gallium, respectively. The predominant crystalline mineral phases in decreasing order of abundance were gypsum, zinc ferrite, anglesite, and jarosite. Rietveld analysis indicated 21 to 27 weight percent amorphous material in the residue. Chemical analysis of different samples revealed that gallium, germanium and indium

Critical Minerals/Recycling

Figure 4

Extraction rates for selected elements by H₂SO₄ leaching.

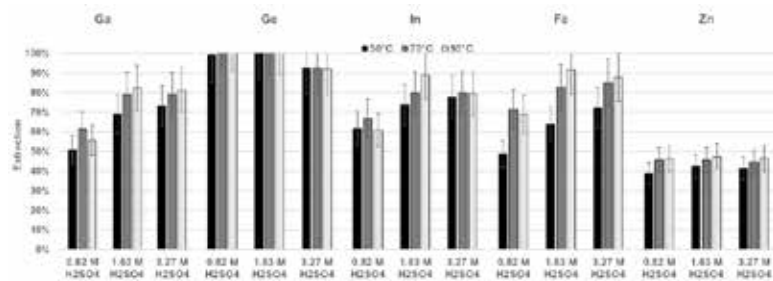


Figure 5

Extraction rates for selected elements by HCl leaching.

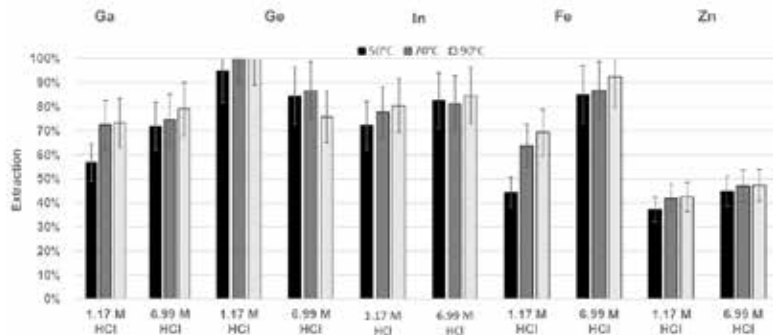
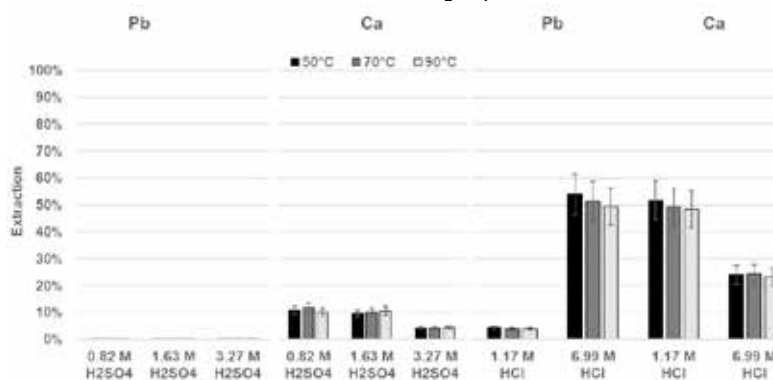


Figure 6

Extraction rates for lead and calcium in H₂SO₄ and HCl leaching.



correlate with iron in the solids.

Heated atmospheric agitation leaching with H₂SO₄ or HCl can result in 82 percent, approximately 100 percent and 89 percent extractions for gallium, germanium and indium, respectively, after six hours. In general, increasing temperature from 50 to 90 °C resulted in higher extractions. Germanium extraction decreased with increasing acidity in both lixiviant systems. Leaching rates showed a correlation between iron, gallium and indium extraction. Indium extraction was less than gallium and germanium, which may indicate a preference for harder-to-leach iron phases. To reduce material costs, avoid the leaching of lead and produce reasonable extraction rates, the preferred leaching condition appears to be 1.63 M H₂SO₄ at 90 °C.

Future work will examine gallium, germanium and indium recovery from sulfuric acid solutions containing iron and zinc.

Acknowledgments

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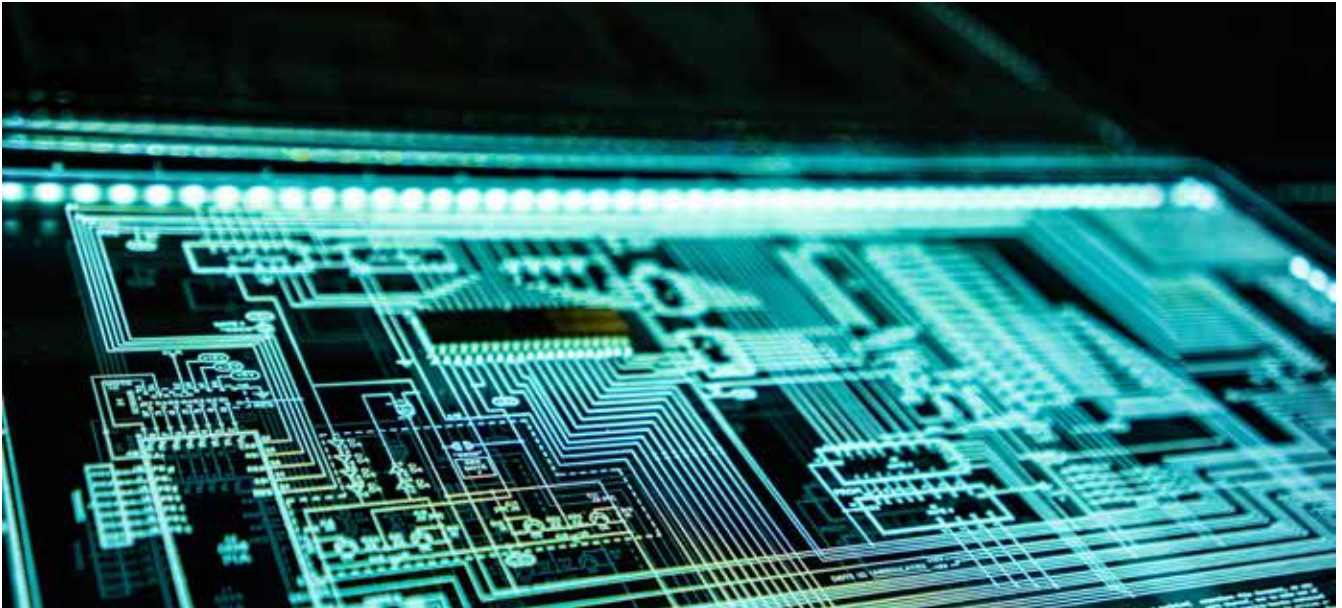
References

- 40 FR 43850 (1975). Environmental Protection Agency, <https://www.epa.gov/stationary-sources-air-pollution/40-fr-43850>.
- Cusano, G., Gonzalo, M. R., Farrell, F., Remus, R., Roudier, S., & Sancho, L. D. (2017). (rep.). *Best Available Techniques (BAT) Reference Document for the Non-Ferrous Metals Industries*. Luxembourg: European Union.
- Ding, Y.-C., Chih-Chien, L., & Cheng, T.-W. (2015). The purification of crude zinc oxide using scrubbing, magnetic separation and leaching processes. *Separation Science and Technology*.
- Foley, N. K., Jaskula, B. W., Kimball, B. E., & Schulte, R. F. (2017, December 19). *Critical Mineral Resources of the United States-Economic and environmental geology and prospects for future supply*. Professional Paper.
- Frenzel, M., Ketris, M. P., Seifert, T., & Gutzmer, J. (2016). On the current and future availability of Gallium. *Resources Policy*, 47, 38–50.
- Licht, C., Peiró, L. T., & Villalba, G. (2015). Global Substance Flow Analysis of gallium, germanium, and indium: Quantification of extraction, uses, and dissipative losses within their anthropogenic cycles. *Journal of Industrial Ecology*, 19(5), 890–903.
- Liu, F., Liu, Z., Li, Y., Wilson, B. P., & Lundström, M. (2017). Recovery and separation of gallium(iii) and germanium(iv) from zinc refinery residues: Part I: Leaching and iron(iii) removal. *Hydrometallurgy*, 169, 564–570.
- Lu, F., Xiao, T., Lin, J., Ning, Z., Long, Q., Xiao, L., Huang, F., Wang, W., Xiao, Q., Lan, X., & Chen, H. (2017). Resources and extraction of Gallium: A Review. *Hydrometallurgy*, 174, 105–115.
- Nassar, N. T., & Fortier, S. M. (2021, May 7). *Methodology and technical input for the 2021 review and Revision of the U.S. Critical Minerals List*. Open-File Report.
- Rao, S., Wang, D., Liu, Z., Zhang, K., Cao, H., & Tao, J. (2019). Selective extraction of zinc, gallium, and germanium from zinc refinery residue using two stage acid and alkaline leaching. *Hydrometallurgy*, 183, 38–44.
- Survey, U. S. G. (2022, January 31). *Mineral Commodity Summaries 2022*. Mineral Commodity Summaries.
- Wu, X., Wu, S., Qin, W., Ma, X., Niu, Y., Lai, S., Yang, C., Jiao, F., & Ren, L. (2012). Reductive leaching of gallium from zinc residue. *Hydrometallurgy*, 113–114, 195–199.
- Zhang, F., Wei, C., Deng, Z.-gan, L.I. C.-xiong, L.I. X.-bin, & L.I. M.-ting. (2016). Reductive leaching of zinc and indium from industrial zinc ferrite particulates in sulphuric acid media. *Transactions of Nonferrous Metals Society of China*, 26(9), 2495–2501.
- Zhu, Y., Deng, Z., Wei, C., Yang, Y., Sun, P., Li, X., Li, M., & Fan, G. (2021). Adaptive process for improving leaching efficiency of germanium from secondary zinc oxide. *International Journal of Chemical Reactor Engineering*, 19(6), 615–623.

Don't let the bad guys win

Everyone has a stake in ensuring the cyber resiliency of our mines

by Heather Ednie, Global Mining Guidelines Group



Cyber-security attacks have increased in mining. Recent reports of operation shutdowns in Canada, Europe and elsewhere demonstrate the criticality of ensuring the cyber resiliency of mining operations — it's not a question of whether an attack will happen, but rather whether it will be successful, and if so, are you set up to minimize the impact of such an event?

But who is overall responsible for the cyber resiliency of a company and its operations? What roles do boards play, or executives? Is it an information technology (IT) responsibility, or does it sit in operations? Should you take a corporate or decentralized approach? What is good practice?

In today's digital world, cyber security is no longer simply an IT problem. As mine operations are digitalized, autonomous equipment is connected, and much of the operational systems are connected through the cloud, hence the cyber risk is elevated. Cyber resiliency has become a crucial requirement that is driving the need for operational technology (OT)/IT integration and turning the lens on supply-chain resiliency to ensure mine operations are protected from cyber weaknesses brought in by suppliers.

Luckily, there are organizations helping advance the mining industry toward a more

cyber-resilient future. The Mining and Metals Information Sharing Analysis Centre (MM-ISAC) brings mining companies together to share threat intelligence, collaborate on best practices, and work throughout the industry to keep our mines and our companies as secure as possible. But where do we start?

Today's threats

On Dec. 29, 2022, Copper Mountain Mining Corp. in British Columbia, Canada, announced that "... the company's IT systems at its Copper Mountain Mine and corporate office were subject to a ransomware attack late on Dec. 27, 2022... The company has isolated operations, switched to manual processes where possible, and the mill has been preventatively shut down to determine the effect on its control system."

It would be well over a week before the mill was back to full production. This major interruption in production could happen to any mining company. In March 2019, Norwegian aluminum processor Norsk Hydro fell victim to an attack that forced its plants across two continents to stop production for almost a week, costing the company more than

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According to the Forbes article on “The True Cost of Cybercrime for Business,” it is estimated that cybercrime has cost organizations approximately \$6 trillion per year on average through 2021.

\$50 million. And there are more examples out there. But how do these attacks happen?

In the case of Copper Mountain, BleepingComputer.com reported that a cyber criminal had offered to sell account credentials belonging to a Copper Mountain employee on a hacker marketplace on Dec. 13, 2022, and suggested it is likely that hackers used a compromised account to gain access to the company’s network.

Phishing emails — bogus emails designed to trick the recipient into providing confidential information — abound. And despite the best training and the best of intentions, mistakes happen and employees (or bosses) click the wrong button.

“Every organization will get phished, and everyone will have someone that will click on something,” said Rob Labbé, founding chair of the MM-ISAC. “The question is, then, how are you going to minimize the impact?”

But emails are not the only access points. With the digitalization of the mining industry and the connectivity across operations and equipment, one of the biggest cyber-security risks today comes from vulnerabilities brought in by vendors, software companies and service providers.

“Anyone with a connection to your network can bring in a vulnerability,” said Cherie Burgett, the MM-ISAC’s director of cyber intelligence operations. “Many vendors need remote access to function, to execute their work.”

Most mining companies use service providers — consultants, third-party IT or management services — who must remotely connect into the company’s systems. These are the systems being targeted. Those tools (third-party systems) are already white-listed, so a breach of them goes undetected and the system is hijacked.

Every software has a vulnerability. Every piece of code can be vulnerable and requires constant updates. Anyone can get phished and can easily give up their passwords to those tools and systems.

“The risk is that it provides an avenue for the bad guys to use those same tools,” Labbé warned. “The tools are there for legitimate purposes. They haven’t knowingly installed something malicious, but hackers are looking for them to use as access points.”

Alex Dow, co-founder and chief innovation officer at Mirai Security, a boutique security consultancy that specializes in mining, works with many different companies and has seen first-hand some of the common cyber risks.

Whereas the major mining corporations tend to have their own internal IT and cyber-security teams, driving toward implementation of best practices and standards, many of the juniors and smaller mid-tier miners often completely outsource IT, and along with it, cyber security.

“Among the juniors, many are going to the Apple store, buying a laptop and that’s it,” Dow said. “And that middle market is generally not internalizing IT but outsourcing to a third party to completely manage it. In these cases, they are less likely to be following the standards but are more often than not doing ‘just-in-time IT’ due to budget and resourcing restraints.”

One major risk of this approach is that without proper processes in place, an attack on one part of the organization can give someone swift access to the rest of the organization. For mining companies, that can mean an attacker that gains access through the IT system can connect into the OT systems.

“Attacks are inevitable now,” Burgett said. “People are targeting mining and they are targeting mining suppliers. But an attack, like a phishing attack, should never extend to your production. Too many attacks are having successful breaches. I think it’s because of an assumption that a cyber attack will never happen, that ‘no one would target our company.’ But you need to assume it will and plan accordingly.”

Cyber security is everyone’s problem

Good practice for cyber resiliency requires a multistaged approach. From the board to the site managers, an integrated framework of responsibilities is needed to guide the best decisions for the company.

The board of directors and senior executive team own the risk, Labbé explained. This includes requirements for reporting, understanding and mitigation. “Cyber risk is material risk that must be managed by the senior executive team and the board, like other material risks to the business. If you’re a large miner, that means your CISO or security leader should be part of the executive management team that

owns that risk. For a smaller miner without a CISO, you need somebody, even a third party, embedded in the executive team to help manage that risk.”

Labbé cautions that many companies still see cyber security as an IT or technology problem, but in reality it is a business or process problem. “Cyber resiliency must be managed as part of the senior executive team and reported to the board. It can’t be buried; it’s too material now. Particularly for mining companies further down the innovation path — for them it’s absolutely critical.”

Cyber security at site

As operational systems become more sophisticated and connected, who, then, is responsible to manage their cyber risk? “Operational technology needs to be decentralized,” Labbé said. “A site has to own their OT, the general manager has to have full management of that. However, cyber security needs to be centralized. This means that at the site level, cyber resiliency is about risk and relationships.”

The integration of IT and OT security is a complex task. One challenge is the tendency for many security practitioners to approach the issue as a technical challenge. “OT security is, in my opinion, one of the most human of all cyber-security domains,” Labbé said. Due to the safety, environmental and other acute risks inherent in most industrial settings, including mines, those operations are built on trust between the people working within it. For the corporate cyber-security personnel coming into the mine, that means they must take the time to build those relationships, understand the mine, its processes, risks and requirements, and earn the site’s trust. “Demonstrate that the site can trust that you will operate safely,” Labbé cautioned. “Never put production or safety at risk at site.”

Cyber security done poorly on the operational side — which can be as simple as blindly applying practices that are accepted in IT to the OT environment — can have devastating effects on production. “You can be worse than any malware and more effective at bringing down operations,” Labbé said. “That risk is real. The general manager sees what we do in IT security and thinks ‘not in my mine.’ In OT, maintaining safety and production comes first.”

On the flip side, site personnel need to recognize that they cannot do this by themselves. They need to understand that cyber security is a risk to reliability and safety at site, and no mine is equipped to — or should be expected to — be responsible for cyber resiliency on their own.

“Site leadership needs to do their half of that trust building,” Labbé said. “Teach the cyber teams the processes about the mine. Meet in the middle. There will be a need for some change to make improvements but that is a plan you should build together.”

Stay away, Chicken Little

In a perfect world, mining companies should isolate the business-critical systems that can interrupt production or hurt people, and minimize the accessibility of those operational systems. However, with the digitalization of mining many more actors require remote connectivity to the systems in the mine. “Unfortunately, for a number of suppliers that have been offering technologies for a decade or more, they had developed their products before this isolation requirement existed,” Dow said.

GMG/MM-ISAC Cyber Security Working Group

The Global Mining Guidelines Group (GMG) facilitates industry-wide collaboration on common challenges, enabling the sharing of experiences and knowledge in a structured way. The GMG/MM-ISAC Cyber Security Working Group aims to foster awareness, develop a culture of cyber security, and provide guidance for the global industry.

Why cyber security matters

Adopting prudent security measures and implementing an integrated cyber-security management framework is essential for any mining organization to prevent service disruption and to be able to react to threats. It is critical to build reliable, secure and resilient mining operations to enable secure convergence between operational technology and information technology (OT/IT), and to drive accountability across the entire value chain.

Everyone is welcome to join and participate in the GMG/MM-ISAC Cyber Security Working Group; membership to either organization is not required and participation is free.

Securing the cyber resilience of mining operations is everyone’s responsibility — it is not just the IT department’s responsibility. The more you know, the better equipped you will be to help prevent a breach or attack. Hackers use sophisticated methods to infiltrate organizations, and access points are plentiful.

Join peers to learn good practices and/or help guide mining stakeholders in their efforts to design safe, secure, reliable and resilient cyber-security infrastructures that adhere to regulatory, trust and privacy best practices. ■

“They built their entire technology and platform around easy connectivity, which was a good offering at the time. However, today we realize that easy accessibility and connectivity to those systems — necessary for operations support — could also enable bad actors who could gravely impact the mine. So, we try to put blockers in place, but it requires very creative network security architectures.”

There is a balance required. On the one hand, major connectivity throughout the mine is a necessity to support the equipment and processes because, at the end of the day, we need to enable the business. But that brings with it heightened cyber risk and often great complexity to mitigate cyber risk across the web of systems in a mine.

“We focus on minimizing the attack surface of a mine, through isolation of systems,” Dow said. “The greater the attack surface, the more likely an unsophisticated attacker could gain access to it.”

Dow’s advice to mining companies is to focus on mitigating the major risk, but not get caught up trying for a perfect solution. “No business can afford to solve all problems, so mine management and executives need to be clear on where the priorities lie,” Dow said. “Otherwise, it results in the Chicken Little syndrome, with the cyber-security team always squawking that the sky is falling.”

There are a few considerations for mining companies:

1. **Common attack patterns:** Groups such as the MM-ISAC enable companies access to mining-curated threat intelligence and can identify typical patterns. Understand what threats are out there and do an internal review to understand how that threat might play out within the business.
2. **Business-critical systems:** Identify what systems are business critical and assess what would happen if an attacker gained access (such as the accounting system, the mobile fleet). How is that system accessible? Can they operate manually? What is the impact of that system going down? What does a bad day look like?
3. **Make cyber security and information security part of the conversation:** Ensure your company has standards and guidance to adhere to. Use tools such as the MM-ISAC threat model. Make cyber security part of the contractual obligation of supply, as well as other site-cyber resiliency aspects such as standards, breach notifications and remote-access requirements.
4. **Business continuity planning/disaster**

recovery planning: Identify the systems required to help you make money and what happens if any one of those systems break.

Dow said, “We all know, for example, that when a haul truck is out of service it means a loss of tons per hour. Now, if the haul truck is autonomous, it relies on more technology and systems to function. If those systems break, can the haul truck operate manually? Then repeat the process across all systems. What is the impact, the cost, of that system stopping, and where does technology touch these systems, providing potential avenues for an attacker? This will map out the cyber-security requirements for your operation.”

Whole-of-industry approach

Cyber resiliency in mining requires a whole-of-industry approach. Groups such as the MM-ISAC and Global Mining Guidelines Group (GMG) are driving industry momentum to ensure all of mining has access to good practices and support to mitigate risks and take action.

“The reality is that we all face the same risks; the same groups are attacking all of us,” Labbé said. “A collaborative approach like the MM-ISAC is like having a neighborhood watch. It provides the ability to share information and see what each other is seeing. It is critical to amass knowledge to protect. No one gains from their cyber security being better than the others’ — there is no increase in dollars per pound of copper. However, the risk of not collaborating on cyber is major; we all stand to lose. It is in your best interest, regardless of your size of operation, to work together.”

As geopolitical risk grows, the positioning of mining and metals at the start of the supply chain for everything makes our industry increasingly a target. Meanwhile, the sophistication of the attacks is only going to get more challenging.

“The good news is that we haven’t been as targeted as other industries like healthcare, retail, and oil and gas,” Burgett said. “In fact, not until recently was cyber risk highly affecting mining. My worry is that we become like healthcare and are slammed constantly. We aren’t there yet, but could be very soon.”

Organizations that do share and collaborate have a greater chance as they benefit from collectively amassing intelligence. “Together we are stronger than the individual sum,” said Labbé. “Collaboration can work well for a small single-line miner or a global major. That is the key going forward. We need to collaborate at an industry-wide level because the bad guys are already collaborating.

The future is uncertain, but there's a light at the end of the tunnel that isn't a train. To get there requires a collaborative approach." ■

Cyber security is a team sport

Working as an industry to identify, detect and protect mining operations

The Mining and Metals Information Sharing Analysis Centre (MM-ISAC) was established in 2018. Sharing communities have evolved into a central point of trust — collecting, analyzing and disseminating actionable intelligence for its members in near-real time.

Threat-intelligence sharing enables community members to defend themselves based upon the threats that federal governments and other peer organizations detect and share. Done correctly, cyber-intelligence threat sharing:

- Speeds attack detection.
- Deepens detection capabilities.
- Produces a timely response to new indicators of compromise (IOC) for other organizations that may likely see the same or similar threats.

Teamwork makes the dream work

The MM-ISAC's goal is to improve the cyber resiliency of the global mining and metals industry.

In the MM-ISAC community there is peer-to-peer sharing through events, webinars and workshops; networking and matchmaking; and efforts to make threat intelligence actionable for its members. These members also collaborate within four working groups:

Cyber security for OT. Focus areas include high-level guidance around OT risk assessment; sharing best practices and what each member is doing; dealing with the Internet of Things (IoT) and cloud architectures as a mining community and dealing with onboard systems available through public websites. Members are currently outlining a project plan to update and expand the MM-ISAC autonomous haulage systems (AHS) threat model.

Internal processes. Focus areas include developing and gathering templates, checklists and more that are specific to the industry; developing an incident response plan, maturity model, and benchmarking mechanism; guidance from peers for a software of security operation center (SOC); building a vulnerability management process; and more.

Threat intelligence and threat hunting.

Focus areas include sharing of peers' findings, intelligence, indicators and how members are handling cyber events; threat hunting; how to collect and communicate threat intelligence with different audiences in a company; how to get ahead of headlines; and more.

Supply-chain resiliency. Focus areas include growing the MM-ISAC cyber-security readiness rating program; helping the vendor community to improve; and how to build highly functional relationships with both vendors and various departments across the mining company.

A centralized and simple approach to risk management assessment

The mining sector relies on third parties to deliver products and services. With the uptick in cyber-security incidents, mining companies are needing to assess additional risks a supplier may bring, typically through the dreaded cyber security questionnaire. But a simpler solution now exists:

- Suppliers: fill out one form that is viewed by many companies.
- Mining companies: fewer forms makes assessing vendor forms manageable.

The MM-ISAC cyber-security readiness rating addresses the increasing security risk within the mining and metals industry supply chain:

- Cyber-security risk rating for vendors.
- Identifies risk management capabilities.
- Assessment of governance and technical capabilities, risk and safety culture.

The result is a cyber-security readiness rating that identifies high-level security and privacy facts that provide security and threat risk assurance that can be leveraged by organizations during the vendor screening and selection process.

Suppliers fill out one questionnaire for potential business with multiple companies.

• **A rising tide lifts all boats.** The MM-ISAC invites all companies across the global mining industry — operators and suppliers — to collaborate toward improved cyber resiliency for all. Readers can learn more about MM-ISAC and how to join the community, or get more information on the group's cyber-security readiness rating by contacting programs@mmisac.org or visiting www.mmisac.org. ■

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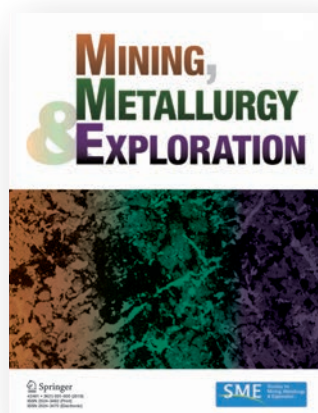
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A rapid review of collision avoidance and warning technologies for mining haul trucks

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Keywords: Collision avoidance, Collision warning, Technology, Mining, Haul trucks

Given the recent focus on powered haulage incidents within the U.S. mining sector, an appraisal of collision avoidance/warning systems (CXSSs) through the lens of the research literature is timely. This paper aims to evaluate the maturity of CXS technology through the application of a technology readiness assessment (TRA) to research literature identified by systematic search methods. Results indicate that much of the evidence for CXS performance is at lower levels of maturity: that is, components and prototypes tested in a laboratory and in relevant environments. Less evidence exists for CXS performance at higher levels of maturity — that is, systems evaluated within operational environments — despite the existence of commercial products in the marketplace. This lack of evidence at higher maturity levels within the scientific literature highlights the need for more peer-reviewed research to evaluate CXS technologies. Additionally, results of the review reveal that most of the literature relevant to CXS technologies is focused on vehicle-to-vehicle interactions, which contrasts

with haul truck fatal accident statistics that indicate most are due to vehicle-to-environment interactions, such as traveling through a berm. Lastly, the relatively small number and segmented nature of relevant studies suggest there is a need for more incremental research that would better facilitate the improvement of CXS technologies. This progression could be achieved through continued long-term interest and support for CXS technology research.

Background

In the wake of many tragic incidents involving powered haulage and mobile equipment, the U.S. Mine Safety and Health Administration (MSHA) issued a request for information (RFI, Docket No. MSHA-2018-0016) in June 2018 on best practices, training materials, technological improvements and other methods for improving miner safety in and around mobile equipment. In particular, MSHA sought information on the role of engineering controls, such as CXS

or other technologies, that would “enhance equipment operators’ ability to see all areas near the machine, warn equipment operators of potential collision hazards, [or] prevent equipment operators from driving over a high wall or dump point.”

While there is evidence to suggest that CXS technologies can help to prevent haul-truck-related collisions, less is known about the current state of the technology, including what type of testing and evaluation has been done, what type of interactions is the technology focused on preventing, and what is the overall direction of CXS technology research. To help characterize the current state of CXS technologies, this paper provides a review and appraisal of scientific literature through the application of a TRA.

A TRA provides a framework that can be used to assess the maturity of technologies in terms of the degree to which those technologies have been demonstrated to successfully operate under the range of conditions encountered during use. A frequently used scale is the technology readiness level (TRL), a nine-point scale that defines maturity from conceptualization to a fully mature, field-deployed technology. Mining-specific TRL definitions developed by Carr (Table 1) were used to ensure that the CXS technologies were being evaluated with respect to mining.

CXSs are technological systems designed to detect objects, warn operators, and/or automatically take action to prevent and mitigate collision accidents involving mobile

equipment. For surface mining, CXSs are typically installed on powered haulage equipment, such as haul trucks, where their operation carries a significant risk of collision with something in the environment, another vehicle or a person on the ground. Most commercially available CXSs are designed to detect objects around the vehicle, especially in blind spots, and inform the vehicle operator and other persons at risk. CXSs may include one or more technologies for detection including cameras, global navigation satellite system (GNSS) receivers, radio detection and ranging (RADAR) sensors, light detection and ranging (LiDAR) sensors, electromagnetic tags and/or radio frequency tags.

Methodology

A rapid review methodology was selected for the search and appraisal of existing research on CXSs and technologies. A rapid review provides a rigorous method for assessing existing literature while reducing the overall scope of the review process by allowing concessions such as focusing the research question, limiting search strategies and/or performing less sophisticated analysis. This study used a rapid review strategy with a search, appraisal, synthesis and analysis (SALSA) framework consisting of: (1) Search: a systematic search of three databases. (2) Appraisal: selection of relevant studies using inclusion and exclusion criteria and grouping by technology category. (3) Synthesis: extraction of relevant data from articles including variables such as study

Table 1 – National Aeronautics and Space Administration (NASA), U.S. Department of Defense (DOD) and mining-specific TRL definitions.

	NASA definition	DOD definition	Mining-specific definition
TRL 9	Actual system “flight proven” through successful mission operations	Actual system proven through successful mission operations	Actual system proven through successful use in active mining operations under the range of conditions expected to be encountered in use
TRL 8	Actual system completed and “flight qualified” through test and demonstration (ground or space)	Actual system completed and qualified through test and demonstration	Actual system completed and demonstrated through field tests
TRL 7	System prototype demonstration in a space environment	System prototype demonstration in an operational environment	System prototype demonstration in a representative operating mine
TRL 6	System/subsystem model or prototype demonstration in a relevant environment (ground or space)	System/subsystem model or prototype demonstration in a relevant environment	System/subsystem model or prototype demonstrated in a relevant environment
TRL 5	Component and/or breadboard validation in relevant environment	Component and/or breadboard validation in relevant environment	Component and/or breadboard validation in relevant environment
TRL 4	Component and/or breadboard validation in laboratory environment	Component and/or breadboard validation in laboratory environment	Component and/or breadboard validation in laboratory environment
TRL 3	Analytical and experimental critical function and/or characteristic proof of concept	Analytical and experimental critical function and/or characteristic proof of concept	Proof of concept established through analytical or experimental means
TRL 2	Technology concept and/or application formulated	Technology concept and/or application formulated	Technology concept and/or application formulated
TRL 1	Basic principles observed and reported	Basic principles observed and reported	Basic principles observed and reported

type, testing methods and metrics tested. (4) Analysis: an analysis of the progression and state of CXS technology maturity through the application of a TRA.

Results

Articles selected for inclusion.

An initial search of three electronic databases (Compendex, Scopus, and OneMine) resulted in 432 articles once all duplicate articles were excluded. The appraisal and synthesis steps of reviewing the articles for inclusion reduced the articles further to 64, or approximately 14.8 percent of the initial search results. However, in the analysis step, several articles were assigned to two or more technology categories in cases where multiple CXS technologies were discussed within the article. This resulted in a total of 97 cases that were analyzed for technology readiness. The full paper shows a flow diagram of the process.

General characteristics of CXS found within included articles. As shown in Table 2, a relatively large portion (39 percent) of articles were solely focused on CXS designed to prevent vehicle-vehicle interactions. Another large portion (22 percent) of articles sought to provide solutions for “All” types of interactions between the vehicle, environment and person. Notably, vehicle-vehicle interactions were represented in 83 (85 percent) of the cases; that is, all technology categories. In contrast, a relatively small portion (11 percent) of articles were solely focused on vehicle-person interactions. An even smaller portion (3 percent) were solely focused on vehicle-environment interactions. All CXS technology categories — such as CAMERA, GNSS, LiDAR — were represented in the vehicle-vehicle interaction category. In comparison, vehicle-environment interactions were only associated with “Other” and “RADAR” technologies.

TRA results. The assigned TRLs for all articles are shown graphically in Fig. 1 by the publication date (year). A large portion (68 percent) of the articles were assigned TRLs in the range of 2 to 4, which are defined as early levels of technology maturity: that is, concept (2), proof of concept (3), component testing in a laboratory (4). Another large portion (24 percent) of the articles were assigned TRLs ranging from 5 to 6: that is, component validation in a relevant environment (5), prototype validation in a relevant environment (6). However, a relatively small portion (8 percent) of the articles were assigned TRLs ranging from 7 to 9: that is, prototype demonstration in an operational environment (7), system qualified through test and demonstration (8), system proven through successful mission operations (9).

Discussion and conclusion

This review and appraisal of peer-reviewed literature identified several gaps where additional research is needed. First, the focus of CXS technologies on vehicle-vehicle interactions may be too narrow given that most haul-truck-related fatalities are due to vehicle-environment interac-

Table 2 — Collision interaction type cross-tabulated by technology category.

Interaction type	Technology category							Grand total
	CAMERA	GNSS	LiDAR	Other	RADAR	TAG	V2X	
Vehicle-vehicle	6	7	2	10	4	2	7	38
All		10		2	2	6	1	21
Vehicle-vehicle and vehicle-environment	2	2	1	3	4	1	3	16
Vehicle-person	2	1		1	2	4	1	11
Vehicle-vehicle and vehicle-person	2			1	4	1		8
Vehicle-environment				2	1			3
Grand total	12	20	3	19	17	14	12	97

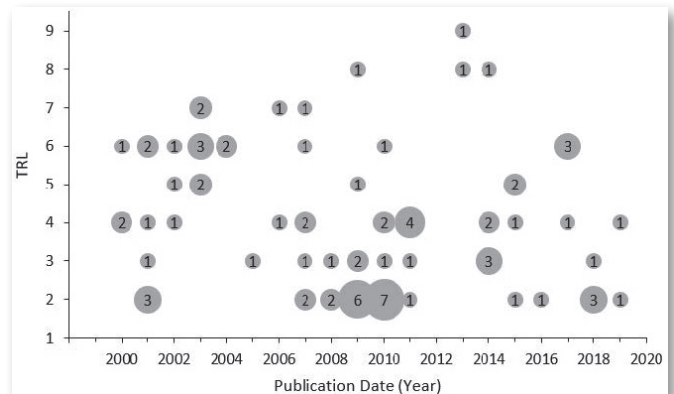


Fig. 1 Technology readiness level (TRL) assigned for all articles by publication date (year).

tions, such as loss of control, rollover, going over a highwall. It may be beneficial for future research to focus on vehicle-to-environment interactions to align with the fatality and injury data. Secondly, the absence of articles demonstrating higher levels of technology maturity indicates there may be a need for more peer-reviewed evidence on the performance of CXSs, which could be achieved through greater collaboration between academia, government research institutions and industry. Lastly, the segmented nature of the published studies indicates there is a need for more stepwise research. In several cases, the technology reached a moderate level of maturity — TRLs 5 to 6 — but it was unclear if the technology was adopted by industry or if research continued. Overall, the mining sector may benefit from more peer-reviewed published work evaluating CXS technologies. ■

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The findings and conclusions in this paper are those of the authors and do not necessarily represent the official position of the National Institute for Occupational Safety and Health (NIOSH), Centers for Disease Control and Prevention (CDC). Mention of any company name or product does not constitute endorsement by NIOSH.

References

A list of all references is available in the full paper.

Design and simulation analysis of dewatering hydrocyclones

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Keywords: Dewatering, Hydrocyclone, Simulation, Efficiency curve, Nageswararao model

The ability to predict the dewatering performance of an industrial hydrocyclone from a laboratory-model hydrocyclone is of great importance. In this study, laboratory-scale hydrocyclone experiments were conducted using silica sand samples at 10 percent solid concentration for dewatering with Mozley hydrocyclones with diameters of 2 in. and 4 in. The objective is to predict the design parameters for an industrial dewatering cyclone to achieve higher solid concentration in the underflow. A model was developed based on the Nageswararao hydrocyclone model with the help of a commercial simulator for a hydrocyclone operating at 100 t/h and 20 percent solid concentration to achieve 80 percent solid recovery at 45 percent solid concentration in the underflow.

Introduction

Dewatering, or the separation of solid from liquid, is an important aspect of mineral processing. Hydrocyclones are found to be efficient dewatering units in the case of fine particles smaller than 150 μm in size. The modeling of dewatering efficiency for industrial-scale hydrocyclones from laboratory-scale experimental studies through empirical modeling has found popularity among practitioners and designers. In this paper, a roadmap is shown for the prediction of a higher-scale dewatering performance from laboratory model data using the Nageswararao model with the help of a commercial simulator.

Materials and method

A series of experiments were conducted with silica sand (80 percent passing through 150 μm , density 2.65 g/cm^3) in the form of slurry with 10 percent solid concentration in a laboratory-model Mozley hydrocyclone with diameter, D_c , of 2 in. The experimental setup consisted of a closed-circuit test rig, the 2-in. hydrocyclone, a mono pump, control valves and pressure gauge along with a bypass line. Experiments were performed at a variable parameter combination of apex or spigot diameter (SPD, D_u) of 3, 5 and 6.5 mm; vortex finder diameter (VFD, D_o) of 8, 11 and 14.3 mm; and pressure of

15, 20 and 30 psi. After attaining steady state, time samples were collected in respective containers from both the exits (underflow

from apex, overflow from vortex finder) simultaneously. The size distribution of both the dried products — that is, underflow and overflow — were analyzed in a Malvern laser diffraction particle size analyzer (dry basis). The cut size, D_{50} , was found from the individual efficiency curve for the respective experiments.

In this paper, the objective was set to achieve 80 percent solid recovery in the underflow with a 45 percent solid concentration from a feed of 20 percent solid concentration according to the dewatering purpose. This target was set to be comparable to the plant requirement. The simulation was conducted for a hydrocyclone with throughput of 100 t/h. The following steps were followed to achieve a result above the target: (1) Development of a mathematical model for the 2-in. Mozley hydrocyclone by calibrating model parameters with the help of a simulator. (2) Validation of the model with both 2-in. and 4-in. hydrocyclones. (3) Development of a new model with the reconciled data for a 4-in. hydrocyclone and validation with other 4-in. hydrocyclone experimental data. (4) Keeping the objective of D_{50} around 20 μm , the cyclone diameter was selected from the chart of cyclone diameter, D_c , versus D_{50} [1]. (5) The rest of the cyclone dimensions for dewatering purpose were chosen based on the general rule [2]. (6) Considering the 4-in. hydrocyclone model parameters, equipment sizing was predicted for a 100-t/h capacity operating at 20 percent solid concentration (feed) to achieve 80 percent solid recovery at 45 percent solid concentration in the underflow.

Results and discussion

The dewatering performance of the experiments was calculated based on the experimental data and presented in the form of solid recovery in the underflow, R_s , and water recovery in the overflow, R_w :

$$R_s = \frac{Q_u C_u}{Q_f C_f} \quad (1)$$

$$R_w = \frac{Q_u (1 - \frac{C_u}{\rho_s})}{Q_f (1 - \frac{C_f}{\rho_f})} \quad (2)$$

where Q_u , Q_f are the volumetric flow rates of the underflow and feed, respectively, and C_u and C_f are the solid concentrations of the underflow and feed respectively. During all of the experiments, the water split in overflow varied between 74 and 87 percent, whereas solid recovery in the underflow was more than 95 percent. D_{50c} varied between 3 and 7 μm . The cut size predominantly depends on design and operating parameters. An increase in VFD leads to an increase in the D_{50c} . However, an increase in SPD leads to a decrease in

Table 1 — Simulated cyclone dimensions.

No. of cyclones	6/8
Diameter (m)	0.150
Inlet diameter (m)	0.400
Cylindrical length (m)	0.200
Apex diameter (m)	0.035
Vortex finder diameter (m)	0.060
Cone angle (degree)	12

D_{50c} . It is perceived that a decrease in VFD and an increase in SPD leads to an increase in pressure drop, which in turn increases the radial acceleration of particles. This leads to an increase in centrifugal force in the hydrocyclone, which leads to an increase in solid recovery in the underflow as well as finer D_{50c} .

With the help of commercial software, model parameters were calculated for 2-in. and 4-in. hydrocyclones. Simulation analysis was conducted with a 4-in. model parameter for scale-up studies (equipment sizing) to treat 100-t/h capacity operating at 20 percent solid concentration to achieve 80 percent solid recovery at 45 percent solid concentration in the underflow. The tentative cyclone dimensions along with number of cyclones predicted from the simulation analysis are shown in Table 1.

Conclusion

With the help of calibrated model parameters and reduced efficiency curve, solid recovery could be predicted with reasonable accuracy during scale-up activity. This model may be an excellent option for the optimization of a running plant circuit. During optimization and scale-up studies, the challenge lies with the proper use of calibrated model parameters. This modeling is useful for designing a new plant circuit of higher throughput from laboratory experimental data. ■

Selected references

1. Olson TJ, Turner PA (2002) Hydrocyclone selection for plant design. Mineral processing plant design, practice, and control proceedings. SME Publ 1:880–893
2. Gupta A, Yan DS (2006) Mineral processing design and operation, an introduction. 1st ed. Elsevier

Evaluation of underground refuge alternatives and explosion survivability: A review

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Keywords: Refuge alternatives, Refuge chamber, Built-in place, Mine explosion, Numerical analysis

Underground mining environments bring with them occupational health and safety issues with some severe dangers, such as mine explosions. During such events, miners may escape using main access openings or find a safe haven like a refuge alternative (RA) to wait and be rescued and evacuated to the surface. In this paper, RAs are explained with their early and current applications. A classification as permanent and portable is detailed, depending on conditions and abilities. This classification is followed by the utilization and survivability of RAs with the requirements and recommendations of the main mining countries. Based on the utilization and survivability constraints, basic human requirements, waiting for a rescue team, and the required physical specifications of RAs during the events are analyzed in detail for various countries with their regulations. Among these, the specification of resistance to explosion is discussed in particular, and studies in the literature are examined in terms of structural deformation.

Introduction

Accidents and emergency events in underground mines can result in serious worker injury or fatality, with underground mine fires, explosions and floods posing the most severe risks to worker occupational safety and health worldwide [1,2]. As the concept and imple-

mentation of RAs have evolved through multiple periods, countries and mining districts, there are many iterations of distinct designs and sizes which are intended to provide a sealed, safe shelter that is separate from the hazardous mine environment during an emergency.

In the United States in 2006, three accidents occurred in a row with a total of 47 fatalities: the Sago Mine Explosion in West Virginia, the Aracoma Alma Mine Fire in West Virginia and the Darby No.1 Mine Explosion in Kentucky. These disasters led to the Mine Improvement and New Emergency Response (Miner) Act of 2006, requiring that breathable air

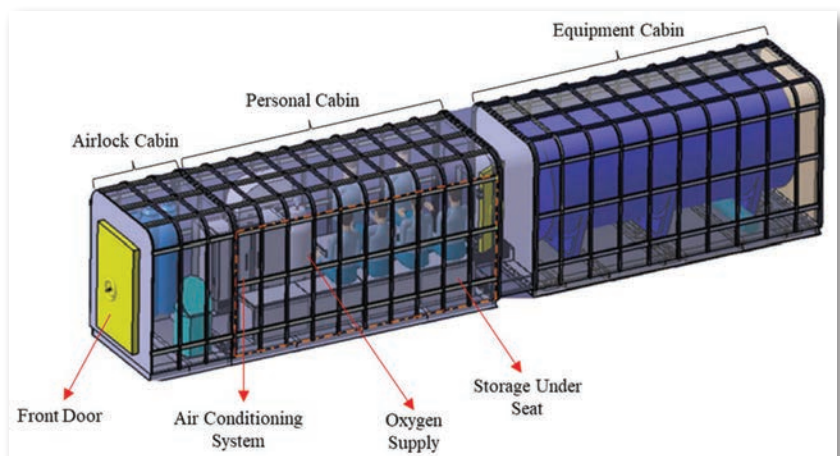


Fig. 1 A schematic view of a refuge chamber [4].

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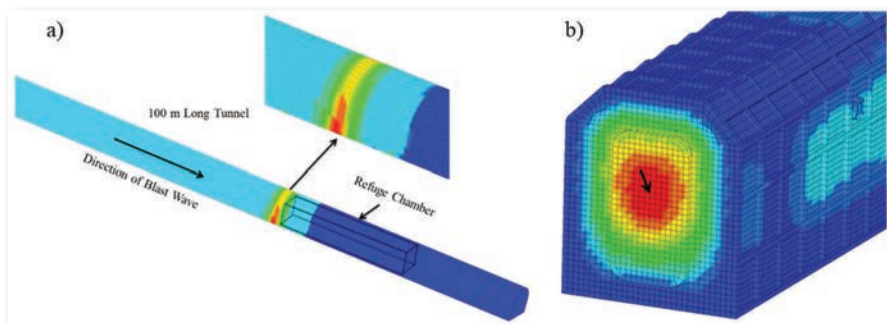


Fig. 2 (a) Explosion simulation through a tunnel with a fluid-solid interaction (FSI) approach. (b) Deformation contour plot of refuge door [5].

be supplied to all miners for 96 hours after an accident [3].

Methodology

Survivability of safe haven. Certain conditions and factors must be met to provide a survivable and sustainable area for miners in the case of several hazardous conditions in addition to fires or explosions, such as blasting, flooding, inadequate ventilation, mud rush and water rush, gas outbursts, geotechnical stability and seismicity, dust, and contaminated atmosphere. The safety of a miner in the context of RA utilization can be examined in two stages: (1) the period upon which a miner can reach an RA and (2) the process of entering and waiting within an RA. While waiting for the arrival of a rescue team, the miners will need some items for basic human requirements, which an RA should include, such as a self-contained self-rescue (SCSR) device, first-aid equipment, fire-fighting equipment and food (Fig. 1).

The ability of an RA to withstand overpressure is one of the most critical design parameters and is directly related to the physical protection of the miners inside the chamber as well as having some indirect consequences. Hence, to withstand the massive shock waves created by explosions and devastation caused by high temperatures, the refuge chamber must be constructed of explosion-proof and fireproof materials. Considering the circumstances that an RA is the last chance for the miners, and damage of the RA is more importantly related to the survivability of the miners, the deformation of the chambers at the time of the explosion is one of the required and quantitative research topics for the protection of mine workers.

Deformation analyses of refuge chambers. The analysis types might be handled under two methods; these are static and dynamic analyses of the deformation. Stress analysis is studied to analyze structures as part of the general design process. Static analysis is frequently used because it is simple to use to determine the failure status. However, in actual physics, dynamic forces are imposed. Real forces, therefore,

behave dynamically. Real and precise phenomena of structures subject to dynamic loads are revealed by transient analysis. However, transient analysis is very expensive and complex by computational means. Therefore, static analyses are preferred for dynamic loading problems as well. In addition to the analysis of RAs, the researchers dealt with either the fully assembled body or only one component focused to be the side-wall, door, and the effect of stiffeners on these walls and doors. It can be easily observed and understood that static loading analysis has received less

attention than dynamic analysis since the loading is actually in dynamic mode. In the literature, the full assembly and/or components of refuge chambers were loaded by varying levels between 0.3 and 1.5 MPa with various pulse widths. The researchers used different codes for the explicit time integration analysis, such as LS-DYNA, AUTODYN, ANSYS, ABAQUS and SOLIDWORKS, with three main steel material models — Q235, 345 and 460 (Fig. 2).

Discussion and conclusion

Based on the findings of this review, regulations pertaining to the construction and utilization of refuge chambers are acknowledged to differ considerably from country to country. This high degree of regulatory variation may be due, in part, to a lack of quantitative information on the performance of RAs. To form such requirements, the design, performance and response of RAs to various emergency situations should be evaluated in a manner which provides useful quantitative information, such as through the use of numerical and experimental studies. In light of this research, significant research gaps have been noticed and recommendations for further studies are given. The numerical studies clearly prove that the most affected parts of the refuge chamber structure during the explosion are the front end, where the door is placed, and the junction of the connected components. ■

Selected references

1. Jakeman M (1998) Developments in self escape and aided rescue arising for the Moura No. 2 Wardens Inquiry-A Special Report by the Joint Coal Industry Committee from Queensland and New South Wales
2. DJF Consulting Limited (2004) Refuge Stations/Bays & Safe Havens in Underground Coal Mining. 3416-001.1. CANMET Mining & Mineral Science Laboratories
3. Mitchell MD (2008) Analysis of underground coal mine refuge shelters. West Virginia University
4. Lei Y, Jiang YL, Zhu CL, Shi H, Wang Y (2011) Strength check and optimization design of movable mine refuge chamber. In *Applied Mechanics and Materials* 66:407–412. Trans Tech Publications Ltd
5. Zhang B, Zhao W, Wang W, Zhang X (2014) Pressure characteristics and dynamic response of coal mine refuge chamber with underground gas explosion. *J Loss Prev Process Ind* 30:37–46

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Evaluation of parameters influencing potential gas flow to the mine in the event of a nearby unconventional shale gas well casing breach

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Full-text paper:

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Keywords: Longwall mine, Shale gas well casing breach

The integrity of unconventional shale gas well casings positioned in the abutment pillar of a longwall mine could be jeopardized by longwall-induced deformations. Under such scenarios, the surrounding fracture networks could provide pathways for gas flow into the mine, creating safety concerns. To provide recommendations for developing guidelines that ensure a safe coexistence of longwall mining and unconventional shale gas production, this study uses a discrete fracture network (DFN) model to evaluate the impact of parameters that could affect potential shale gas flow into the mine in the event of a casing breach. These parameters are evaluated using a conceptualized DFN realization that is representative of the fractured zone in the overburden, and the range of parameter variations are within values validated with field measurements.

Background

Due to the recent boom in the U.S. energy industry, there has been a significant increase in the number of shale gas wells in Pennsylvania, West Virginia, Ohio, Virginia and Tennessee. Though these wells are targeting the Marcellus Shale resource at depths varying from 1,500 to 2,700 m [1], they penetrate through different coal seams at shallower depths.

Method

Figure 1 illustrates a mine site coexisting with shale gas well production in southwestern Pennsylvania. The shale gas well penetrates through the two coal seams in the overburden and the Pittsburgh coal seam mining horizon.

At the mining horizon, the gas well casing must be protected by a coal pillar [2]. From longwall mine data in Pennsylvania, mining depths in these regions could vary from about 94 to 366 m (310 to 1,200 ft) [3]. In the county of Belmont in Ohio, most Pittsburgh coal bed occurrences are within 305 m (1,000 ft) from the surface [4].

Over the next 10 years, many shale gas wells will be mined by Pittsburgh Seam longwalls. Though coal mining and conventional natural-gas production have coexisted for many years, these unconventional wells are characterized by significantly higher-pressure gas. This presents a new array of concerns as mining could jeopardize the integrity of the casings, which could lead to the release of high-pressure gas into the overburden. Therefore, this study develops a conceptualized DFN model to conduct a parametric study on the influence of different parameters on shale gas flow to the mine in the event of a casing breach.

Figure 2 shows a representation of the conceptualized DFN model with all the fracture ends numbered and identified as nodes. This is based on the approach presented by

Priest [5] for flow through discontinuities and also used in a prior study by Ajayi and Schatzel [6]. The model shows 10 external nodes (1 to 10) along with nine internal nodes (11 to 19).

Results and discussion

The findings show that:

1. Methane generation along the fracture network could significantly change the overall gas flux to the mine. Hence, it is likely that a similar casing breach could generate different gas fluxes if there is a gas-bearing stratum along the flow pathway.
2. The presence of immobile water in the fracture reduces the risk of gas flow to the mine by decreasing the proportion of the fracture aperture that is available for gas flow.
3. Under the same flow condition, a change in the gas pressure directly affected the overall gas flow in the same proportion.
4. The aperture of the fracture directly connected to

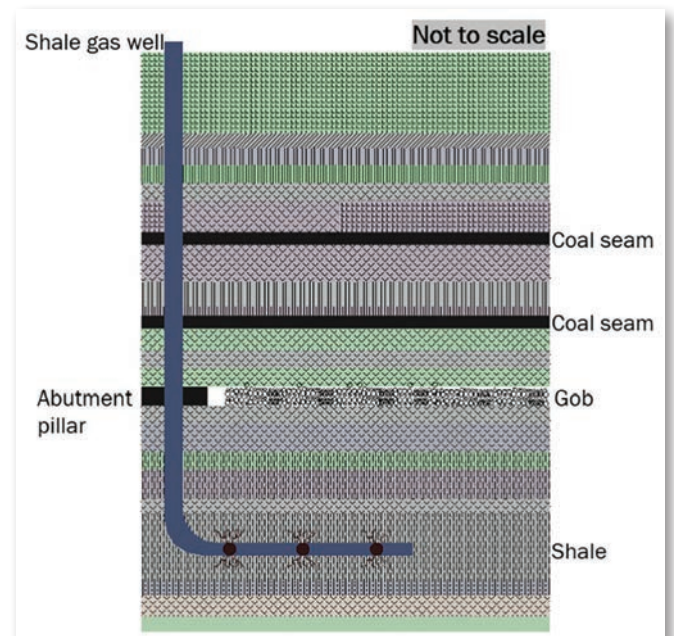


Fig. 1 Schematic of a shale gas well casing positioned in the abutment pillar of a longwall mine, showing the penetration of multiple coal seams.

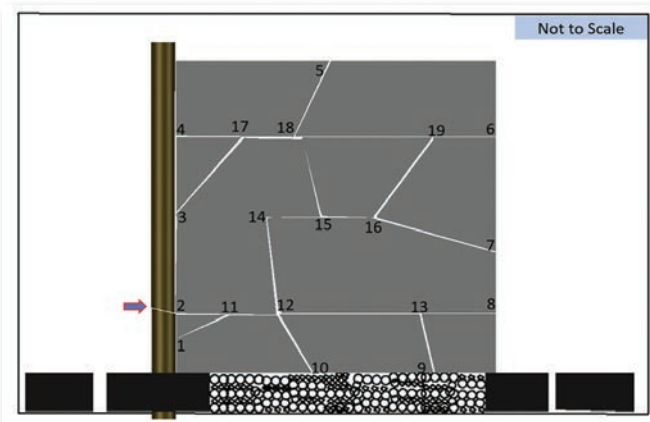


Fig. 2 A representation of the conceptual/deterministic discrete fracture network (DFN) used for this study. The arrow indicates the breach location. Nodes 1 to 10 are external nodes and nodes 11 to 19 are internal nodes.

the casing breach is a critical parameter that significantly influences the gas flow from the breach location. Hence, the coal pillars where gas wells are positioned should be designed to minimize the aperture of mining-induced fractures near the well casing.

5. The distance from the position of the gas well cas-

ing to the edge of the panel has an impact on the potential gas flow.

Conclusion

Overall, these findings provide critical information that could contribute to the development of guidelines to proactively mitigate shale gas flow to the mine in the event of a casing breach. ■

Disclaimer

The findings and conclusions in this manuscript are those of the authors and do not necessarily represent the official position of the National Institute for Occupational Safety and Health (NIOSH), Centers for Disease Control and Prevention (CDC). Mention of company names or products does not constitute endorsement by NIOSH or CDC.

Selected references

1. Zhang P, Su D, Lu J (2019) Influence of longwall mining on the stability of shale gas wells in barrier pillars. American Rock Mechanics Association. New York.
2. Commonwealth of Pennsylvania, Department of Mines and Mineral Industries Oil and Gas Division (1957) Joint coal and gas committee, gas well pillar study. Harrisburg, Pennsylvania, 28 pp
3. Pennsylvania Department of Environmental Protection. Longwall mine data (cited 29 September 2021)
4. Berryhill HL (1955) Coal reserves of the Pittsburgh (no. 8) bed in Belmont County, Ohio
5. Priest SD (2012) Fluid flow in discontinuities, in discontinuity analysis for rock engineering. Springer Science & Business Media
6. Ajayi KM, Schatzel SJ (2020) Transport model for shale gas well leakage through the surrounding fractured zones of a longwall mine. Int J Min Sci Technol

A numerical modeling approach for the assessment of seepage characteristics and performance of protective water barrier pillars in underground coal mines

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Full-text paper:

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Keywords: Underground mine, Protective water barrier pillars, Pillar design, Hydromechanical modeling, Water seepage, Permeability

This paper proposes a hydromechanically coupled numerical modeling approach to quantify the influence of various parameters on the mechanical and hydraulic performance of protective water barrier pillars (PWBP). The results are validated for two case studies having pillar widths of 16 and 42 m at cover depths of 136 and 190 m and water heads of 25 and 141 m. The outcome can be significantly helpful in the rational design of these pillars in underground coal mines.

Background

Several underground coal mines are facing the high-risk hazard of inundation from waterlogged workings. Excessive seepage creates an additional problem of increased water handling. Providing a suitable size of PWBP is a predominant practice for protection against such danger. Inadequate PWBP width is a crucial reason for inundation disasters in

underground coal mines [1-3]. A survey of 79 coal mines in India revealed that pillar width was less than the minimum regulatory limit of 60 m [4] in more than 50 percent of the cases.

Method

A parametric study based on numerical simulation was conducted to investigate the effects of cover depth from 100 to 350 m, pillar width from 5 to 120 m, extraction percentage from 35 to 41, permeability from 0.01 to 100 md and water head from 25 to 100 percent of the cover depth on the mechanical and hydraulic response of a barrier pillar. The induced porosity and permeability were updated as a function of volumetric strain using the following equations [5,6]:

$$n = 1 - \frac{1 - n_0}{1 + e_p} \quad (1)$$

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$$k = k_o \left[\left\{ \left(\frac{1}{n_o} \right) (1 + e_v)^3 \right\} - \left\{ \left(\frac{1-n_o}{n_o} \right) (1 + e_v)^{-1/3} \right\} \right]^3 \quad (2)$$

where n is porosity, k is permeability, n_o is the initial porosity, e_v is volumetric strain, and k_o is the initial permeability.

Results

For a fixed height, the pillar width acted as a critical parameter to define its mechanical and hydraulic competence. With a decrease in the width, the extent of the intact zone in the pillar, as well as the magnitude of the confining stress, decreased (Fig. 1a). The reduction in width of the intact zone caused an increase in induced permeability in the pillar (Fig. 1b). The resultant seepage from the pillar increased due to the reduced confinement and the increased induced permeability. The seepage increased proportionally with an increase in the induced permeability for a constant water head at a given cover depth.

With the decrease in pillar width and material strength and increase in cover depth, the width of the intact zone decreased, and the percentage of failed zones (ZoF) increased. The rate of water seepage increased with the increase in the cover depth for a given water head. The seepage rate intensified with the reduction in width of the pillar. The material strength of the coal seam showed a more significant effect on the seepage rate at higher depth of cover. The impact of material strength on the hydromechanical stability of the pillar was more pronounced for the smaller width of PWBP. A relationship was developed to estimate the seepage rate through a protective barrier:

$$Q = \frac{0.12k\sigma_c^{0.076}D^{1.288}H^{1.01}}{\sigma_t^{0.047}S_{Hi}^{3.318}\left(\frac{w}{h}\right)^{1.076}e^{0.686}} \quad (3)$$

where Q is outflow through the protective water barrier pillar in gal/min/km, w is the width of PWBP in meters, h is the pillar height in meters, e is the extraction ratio, S_{Hi} is the in situ horizontal stress in MPa, k is the in situ permeability in mD, σ_c and σ_t are rock-mass compressive and tensile strengths of coal in MPa, D is the depth of coal seam in meters, and H is the water head in meters.

For mine A, the estimated ZoF was 83 percent, while the rate of water seepage was 190 gal/min/km for a pillar width of 42 m at a cover depth of 195 m. In contrast, the ZoF in the pillar with width of 16 m in Mine B at a cover depth of 136 m was 19 percent while the seepage was 145 gal/min against a water head of 25 m. The severity of the seepage was “very low.” These findings were remarkably close to the field observations, which confirmed that these barrier pillars were producing insignificant seepage and serving their long-term design function.

Conclusions

The mechanical failure of protective barrier pillars is a stress-controlled phenomenon, while their hydraulic failure is strain controlled. The mechanical stability of barrier pillars is explained by the ZoF. Pillars having ZoF lower than

70 percent are “stable,” while pillars with 70 to 90 percent of ZoF are “critically unstable” and pillars with more than 90 percent ZoF are mechanically “unstable.” The rate of outflow increased significantly as ZoF exceeded 70 percent and became exponentially high for ZoF exceeding 95 percent, indicating its unstable behavior. The governing relation for water seepage through the barrier pillar explained the field observation and the model findings closely. The barrier with width of 42 m in mine A against a water head of 141 m at a cover depth of 190 m, and the barrier with width of 16 m in mine B against a water head of 25 m at cover depth of 136 m, were stable. ■

Selected references

- Galav A, Singh GSP, Sharma SK (2021) Design and performance of protective water barrier pillars for underground coal mines in india—a review. *J Inst Eng India Ser D* 102:539–547
- Job B (1987) Inrushes at British collieries: 1851 to 1970. *Colliery Guardian* (UK) 235(5):192–199
- Dash AK, Bhattacharjee RM, Paul PS (2016) Lessons learnt from Indian inundation disasters: An analysis of case studies. *Int J Disaster Risk Reduction* 20:93–102
- DGMS (2017) The Coal Mines Regulations 2017, Dhanbad, India. p 121
- ITASCA (2011) FLAC: Fast Lagrangian Analysis of Continua. Itasca Consulting Group Inc., Minneapolis
- Zhu H, Zhao X, Guo J, Jin X, An F, Wang Y, Lai X (2015) Coupled flow-stress-damage simulation of deviated-well bore fracturing in hard-rock. *J Nat Gas Sci Eng* 26:711–724

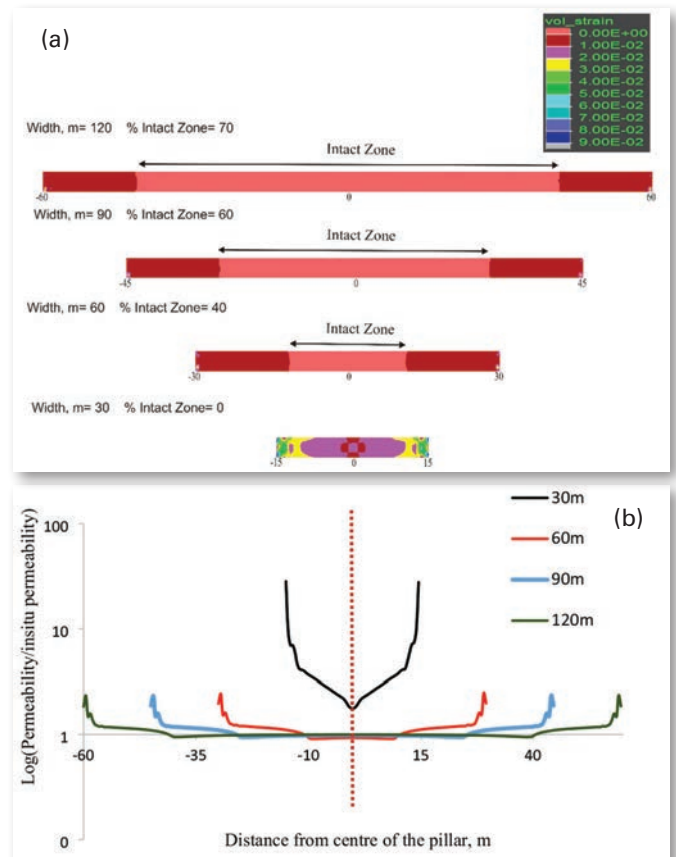


Fig. 1 (a) Volumetric strain contour and (b) induced permeability across different widths of barrier pillars with height of 3 m and soft coal at a depth of 350 m.

Cruising OneMine.org just got simpler; SME web team launches upgrades and enhancements

by Krunal Patel and Chris Ryckley, Web Development, SME

The SME web development team is pleased to announce upgrades and enhancements to the OneMine.org website. These include:

- Improved search with more accuracy and clarity.
- New enhanced search options, including by topic, category and submitting organization.
- Faster access to more than 136,000 technical documents.
- 14 global contributing associations that vet and upload the latest technical information in one central location.
- A streamlined experience across all devices.
- Improved mobile conversion rate.
- Improved user experience, clean invoices, and a search-engine-optimization, user-friendly link

structure.

- Much faster page load, download and search speeds.

You can access OneMine.org easily:

1. As a member benefit of one of the participating society members, you can download an unlimited number of documents at no additional cost.
2. You can use your corporate or library subscription to access documents.
3. Or you can purchase documents for \$25 per paper.

OneMine.org® is your one-stop digital research resource.

Explore the new website at: <https://onemine.org/>. ■

Colorado School of Mines receives \$7.5 million investment from J. Steven Whisler

Colorado School of Mines' mining engineering program has received a historic \$7.5 million investment from alum J. Steven Whisler and his wife, Ardyce, of Whitefish, MT. It is one of the program's largest gifts since the public research university in Golden, CO, popularly known as Mines, was established in 1874 to support Colorado's booming mining industry.

"Mines has the best mining engineering program in the world, and Ardy and I are pleased to provide meaningful support to create an even better mining engineering educational experience for students," said Whisler, a retired mining executive who earned a master's degree in mineral economics at Mines in 1984 and received an honorary doctorate in engineering in 2001. The investment creates the J. Steven Whisler Chair for the Head of Mining Engineering, the J. Steven Whisler Professor of Practice

and the J. Steven Whisler Scholars Program, which funds scholarships for mining engineering students.

"We want to support the department's evolution under a visionary leader and a faculty member who will develop and lead forward-looking strategic initiatives, while giving students financial support to enable them to pursue careers in the mining industry," he added.

The Whislers' investment comes as the number of U.S. mining engineering students is shrinking — by nearly half from 1,449 in 2015 to 736 in 2020, according to a story in the December 2021 issue of *Mining Engineering*. And fewer than 200 students on average are graduating each year.

"Mining companies not only have to compete among ourselves for the best talent, but with other industries such as tech firms in the Silicon Valley," Whisler said. "It's critical that we continue to create a positive reputation and work environment for the industry that will attract and retain new talent to the profession."

He said Mines students go through a trial by fire that prepares them for a career that requires resilience.



J. Steven Whisler

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Meet the new M&E Division Chair; Brad Dunn is geologist at Barr

by Jenessa Haarala

The new Chair of the Mining & Exploration (M&E) Division is Brad Dunn. Dunn is a senior mining geologist for Barr Engineering. He helped establish the Salt Lake City, UT branch of Barr in 2016 and continues to provide leadership to the office in addition to his geology consulting work. He lives in Salt Lake City with his wife, Stephanie, and two children Alice, age 12, and James, age 7.

Dunn grew up in the small town of Waikouaiti in southern New Zealand. While the main industry in the area is farming, many people from the town also work at the nearby Macraes Gold Mine for Oceana Gold, so Dunn was familiar with mining from a young age. He comes from a mining family; his father was an underground coal miner and his brother was an underground gold miner. Upon graduating from high school, he found himself unsure of what degree to pursue at university and decided to spend a year working at the mine. He started out in the assay lab sweeping floors and preparing samples, eventually working his way up to performing fire assays. Macraes is a low-grade gold deposit, typically mining grades of 0.5 to 1 g/t, and as such Dunn learned early on the importance of good sample preparation and representative samples. He found his work at the mine interesting and decided to pursue a degree in geology at the University of Otago in Dunedin.

While attending university, Dunn continued to work at the Macraes Mine on the weekends, paying his way through school and gaining valuable industry experience at the same time. During his senior year, he met an exchange student from the United States named Stephanie who was spending a year abroad studying art and design at the University of Otago. Dunn earned his B.S. degree in geology in 2000 and began to work full time at the Macraes Mine after graduating. Stephanie moved to New Zealand full time upon completing her degree.

Dunn worked as a mining geologist at Macraes until 2007, primarily at the Frasers pit. His tasks included working as an ore spotter supervising ore zone mining in the pit to help reduce the waste that was hauled to the mill. Working at such a low-margin property continued to stress to him the importance of good grade control practices and sampling accuracy. He and Stephanie married in 2007 and decided to move to her home area of the Twin Cities in Minnesota in 2008.

Dunn started his career in the United States as a

contract geologist logging core for the Tamarack nickel deposit in central Minnesota. He started working for Barr Engineering in November 2008. He had been a member of the Australasian Institute of Mining and Metallurgy (AusIMM) when he worked in New Zealand and had always thought that SME sounded like a great organization, but never had the chance to be involved. Upon moving to Minnesota, he took the opportunity to become active in the Minnesota Section of SME, which he found highly rewarding. He began attending the national SME conferences, volunteering in the technical programming, and eventually becoming a member of the M&E Division Executive Committee. When Barr decided to open an office in Salt Lake City in 2016, Dunn was given the opportunity to relocate from Minnesota to Utah and help his company get the office up and running. He and his young family have enjoyed living in the area ever since.

The chance to work on diverse and exciting projects is one of the things Dunn loves about working in the consulting side of the mining industry. One of the most exciting projects he has worked on was as a NI43-101 QP for a resource estimate of a rare earth element deposit in northern Saskatchewan. Traveling to the remote Hoidas Lake deposit required multiple plane flights and one helicopter flight. The project is still in feasibility, mostly due to its extremely remote location. Thinking back on advances in the mining industry over his career, Dunn is excited to see the adoption of new technology in mining as exemplified by the move toward autonomous and battery equipment. Mining obviously plays a critical role in the production of electric vehicles, and he enjoys seeing more mining companies incorporating the technology at their sites.

His favorite thing about SME is all of the great friendships and connections he has made over the years, particularly as he moved to the United States knowing no one but his wife's family and a small circle of friends. He enjoys the opportunities to mentor young SME members as well as the chances to be mentored by members with more experience than him. He appreciates that volunteering within SME allows him to give back to the organization in a way that works well for his current lifestyle.

As M&E Division Chair, Dunn's primary goal is to establish a new scholarship for students attending trade schools. The mining industry is facing a major shortage of tradespeople such as mechanics and electricians. He views this as a great opportunity for the Society to give back and help sustain the industry. There are still many details to figure out, so anyone interested in helping can reach out to Dunn. Once he is finished with his commitment to the M&E Executive Committee, Dunn plans to stay involved in the M&E Division, the technical programming and hopefully get more involved in the recently relaunched Utah Section. ■

Rock in the Box serves as a forum for the presentation and discussion of facts, ideas and opinions pertaining to the interests and technology of the Mining & Exploration Division. Accordingly, all material published herein is signed and reflects the individual view of the authors. It is not an official position of SME or the division. Comments by readers will be referred to that division for response. The division chair in 2023 is Bradley Dunn.

Get ready for the XXXII IMPC... returning to the United States in 2024 after 29 years

by Tarun Bhambhani, MPD Executive Committee

After 29 years, the United States will once again host the International Mineral Processing Congress (IMPC) from Sept. 29 to Oct. 3, 2024 in Washington, DC/National Harbor, MD. SME is the host organization, and the conference is chaired by former SME President John O. Marsden of Metallurgium. Ronel Kappes from Newmont and Tarun Bhambhani from Solvay are co-chairs.

The IMPC draws together the world's leading experts from academia, industry and government to promote, discuss and reveal the latest advances in the science and technology of mineral processing worldwide.

The International Mineral Processing Council has done much to promote cooperation between the various national mining/processing organizations and has provided frameworks for education and sustainability in the field. A major focus for this edition of the conference is to provide a forum for meaningful interactions between academia and the mining industry.

The theme for the XXXII IMPC is "Mineral Processing for the Energy Transition." The structure of global energy supply and demand is undergoing a dramatic transformation with shifts toward renewable and alternative sources of electric power and the electrification of transportation. This energy revolution will be enabled by the supply of the many metals and minerals required to support existing and new methods of electricity generation, electric vehicles, power infrastructure, and small- and large-scale energy storage. With projected shortfalls in metal and mineral production, sustained improvements in the processing of ores and secondary raw materials will be critical to this transition.

The program committee is projecting the presentations of more than 300 peer-reviewed papers across six main focus areas:

- Energy minerals.
- Human capital.
- New processes and technologies.
- Integrated value chain.
- Optimization of existing processes.
- Sustainability.

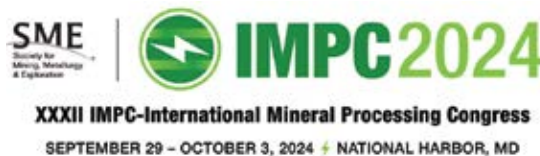
A global panel of experts in these fields has been assembled to organize the technical program. Both oral presentations and poster formats will be available, and the call for papers was opened on March 1, 2023. A written manuscript is required for all submissions.

The committee is also working to put together the prestigious Congress Banquet to honor various award recipients, a cultural showcase evening event, a spousal program, and field trips to relevant facilities nearby. In addition, an area has been

earmarked for exhibits.

A limited number of sponsorship opportunities will also be available. To secure your sponsorship, please reach out to Marsden, Kappes or Bhambhani or to Emma Salditt at salditt@smenet.org.

So mark your calendars for 2024 and prepare for an exciting return of the IMPC to the USA. ■



Fine Grind serves as a forum for the presentation and discussion of facts, ideas and opinions pertaining to the interests and technology of the Mineral & Metallurgical Processing Division. Accordingly, all material published herein is signed and reflects the individual views of the authors. It is not an official position of SME or the division. Comments by readers will be referred to the division for response. The division chair in 2023 is David G. Meadows.

Colorado School of Mines

(continued from page 40)

"They have a stick-to-it attitude that's refreshing," he said. "Mining today depends on people who are prepared to work on a problem until they solve it. That's what I've seen Mines graduates do, and do well."

Whisler spent his career in the mining industry, working his way up from summer intern to chairman and chief executive officer of Phelps Dodge Corp., where he retired in 2007 after overseeing the company's \$26 billion sale to Freeport-McMoRan Inc.

"The industry needs engineers who possess not only

the necessary technical qualifications but also have contemporary and astute cost/benefit analysis and problem-solving skills to assess mineral production opportunities both from a company viewpoint and, as importantly, a societal perspective," he said. "This is particularly important as the production of key minerals will drive and ultimately determine the success of the world's alternative energy policies and strategies."

Mines president Paul C. Johnson said the Whislers' historic investment gives the department resources to be the exemplar and leader that all other universities will want

(Continued on page 45)

Environmental division welcomes students, industry professionals and academics to join

by Julie Neilson



As we conclude the MINEXCHANGE 2023 SME Annual Conference & Expo in Denver, CO, we welcome students, industry professionals and academics to join the SME Environmental Division (ED).

We hope you had the opportunity to stop by our booth in Denver. As a member of the Environmental Division of SME, you have access to professional networking and leadership opportunities with peers who share your career objectives.

Students are provided a great opportunity to explore careers by networking with potential future employers.

The SME ED also provides a forum for the exchange of technical information, publishing technical papers, and organizing technical meetings and programs.

For more information, visit the division's website at www.smenet.org/Divisions/Environmental-Division. ■

Environmental Division News serves as a forum for the presentation and discussion of facts, ideas and opinions pertaining to the interests and technology of the Environmental Division. Accordingly, all material published herein is signed and reflects the individual view of the authors. It is not an official position of SME or the division. Comments by readers will be referred to that division for response. The division chair in 2023 is Jen Pepe.

Central Wyoming Section presents five scholarships to students

In January 2023, the Central Wyoming Section was honored to present the Coates, Russel, Wolff & Swank scholarships to five college students interested in pursuing careers in a mining-related discipline.

Each student had submitted an essay related to the "importance of mining in Wyoming." This year, the scholarships recipients were awarded \$2,000 each. They are students Jack Larson, Sage Wright, Wayne Burk, Zach

Tenney and Jocelyn Olsen.

The Central Wyoming Section is committed to supporting a sustainable mining industry in Wyoming and the United States by providing scholarships and awards to those interested in promoting or pursuing a mining-related career. The section has provided scholarships to teachers, high school students and college students for the past 30 years, totaling more than \$360,000. ■



From left to right: Scholarship recipients Jack Larson, Sage Wright and Wayne Burk with Central Wyoming Section vice chairman Wayne Heili. Not pictured: Zach Tenney and Jocelyn Olsen.

Mining and Metallurgical Engineering page now live on Discover Engineering Website

SME is proud to announce that Mining and Metallurgical Engineering is now listed on the Discover Engineering STEM Careers section on DiscoverE.org. Visit the website at: discovere.org/stem-careers/mining-and-metallurgical-engineering/.

SME joined DiscoverE's Coalition Partnership and Advisory and Diversity Council Membership to further enhance the Minerals Education Coalition's (MEC) efforts in public education and awareness to K-12 teachers and students. Discover Engineering is a nonprofit organization



that is focused on giving every student a shared STEM experience and the resources, programs and connections to improve their understanding of engineering through a united voice and a

global distribution network. Their programs are effectively reaching millions of K-12 educators, students and young adults with the aim of advancing the understanding of engineering and technology.

Upon finding that mining engineering was not listed as an engineering discipline on the Discover Engineering STEM page, Dave J. Soukup, ASME managing director for governance, and Dave Kanagy, SME Executive Director, recommended that MEC work with Discover Engineering to include it. "I am all in to help support an engineering focus in schools to help get more kids into STEM," said

Kanagy.

Within only a few months, Mining and Metallurgical Engineering is now listed on the Discover Engineering STEM Careers section as a specific discipline, with a specially curated Mining and Metallurgical Engineering page featuring:

- "What do you do as a mining or metallurgical engineer?"
- "Mining and Metallurgical Engineer Overview," including salary and anticipated job growth.
- "Jobs and Education" (four-year degree, two-year degree, and high school diploma).
- "Real World Civil Engineering Projects" examples.
- Hands-on, topic-related "Engineering Activities."
- DiscoverE "Chat with the Change Makers" featuring Emily Rose, an SME member and mining geotechnical engineer. If you missed it, you can view it on demand at discovere.org/engage/chats-with-change-makers, and find Emily's activity in a short video along with written instructions at discovere.org/stem-activities.
- A direct link to the following SME websites: Society for Mining, Metallurgy & Exploration homepage, Minerals Education Coalition, Jobs of Tomorrow.

SME is proud and pleased to work with Discover Engineering to educate teachers, students and the public about the importance of mining and minerals in our lives. ■

Excellence in Prospecting Award to Jill Nelson

Jill Nelson, managing founder of Brooks & Nelson LLC, is the 2022 SME Foundation Excellence in Prospecting award recipient.

This award proudly recognizes Nelson for her significant contributions and dedication to SME Foundation fundraising. Her commitment and outstanding efforts in securing major contributions have strengthened the mission and vision of the foundation.

Nelson is a mining engineer who started her career with Shell Mining Co. She moved into the waste industry for BFI, managing closure projects, environmental, health and safety (EH&S), before managing hazardous waste landfills at the Rocky Mountain Arsenal. Later, she returned to BFI as landfill sales manager.

Contributing to her alma mater, Nelson spent three years fundraising for South Dakota School of Mines & Technology (SDSM&T), focusing on the mining sector.

In 2008, Nelson moved into recruiting in the mining industry with Downing Teal in Denver, CO. In 2016, she started Brooks & Nelson with Lois Brooks to provide

exceptional, client-tailored recruiting. Matching top-end talent with the right opportunities is her passion. Nelson is a staunch supporter of the mining industry and serves on the boards of trade associations, colleges and Colorado's Mine Land Reclamation Board.

Nelson has been an SME member since college and has renewed her membership every year since 1993. She has served on the SME Foundation Board of Trustees and as a member of the SME Foundation Corporate Giving Committee since 2016. She also serves on the SME Foundation Scholarship Committee and is a member of the Mining & Exploration Division. ■



Jill Nelson

Gregory Douds Patterson

Gregory Douds Patterson of Charleston, WV, passed away peacefully, surrounded by the love of his family, on Jan. 2, 2023, after a long journey with dementia. He was 71 years old.

Patterson is survived by his wife of 41 years, Corleen Barker and their four children: Emily of Charleston, WV; Abigail of Charleston, SC (husband James, son Forrest, stepdaughter Stormy); Adam of Irwin, PA (wife Erin, daughter Rosalie, son Maxwell); and Will of Charleston, WV. Born on Oct. 11, 1951, to a family deeply rooted in the coal mining industry, Patterson grew up in Yatesboro, PA. He was the first son born to parents of four daughters, and their close-knit community welcomed him with eager and open arms.

Patterson was active in sports and the outdoors as a child and graduated as the salutatorian of Shannock Valley High School in 1967. He attended Penn State, completing a B.S. in mining engineering (1974) and gaining extensive experience as an underground laborer through their co-op program. He moved to the Kanawha Valley in 1974 to work for Bethlehem Steel at their Boone County operations. There, he rose through the ranks at the #131 and #132 mines, eventually assuming the roles of general mine foreman and superintendent.

In 1986, Patterson joined J.V. Services, an underground coal company headquartered in Danville, WV. While with J.V. Services, he earned his MBA from the University of Charleston (1987) before assuming the role of vice president in 1989. During his time with the company, he oversaw their operations in West Virginia, Ohio and Pennsylvania and was promoted to president and general manager in 2004. In 2013, Patterson began working for Norwest, where he had the opportunity to travel to India on a mine consulting venture.

Throughout his career, he was involved with the management of 47 different underground coal mines. His ideal day at work was spent underground at one of his operations interacting with his employees. He was the seventh generation of Pattersons to work in coal, and he was forever proud to see his son, Adam, join the industry. His commitment to the industry was evident in his membership in the West Virginia Coal Mining Institute

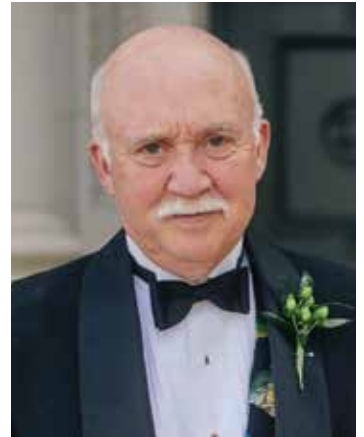
(former president), the Kanawha Valley Mining Institute (former vice president), Careers in Coal, and SME. Patterson's storied career was capped with his election to the Kanawha Valley Mining Institute Hall of Fame in 2012.

Patterson was an avid reader, outdoorsman and golfer, a lover of music and college football, and an all-around great guy to know. He was never afraid to lend a hand or solve a problem, even if it meant driving from Charleston to Morgantown and back in the same day. He made himself at home in the kitchen just long enough to prepare delicious meals for his family and friends, but never quite long enough to clean up.

Whether brave or a little crazy, he enjoyed many weekends alone with his children in Tucker County, fishing and exploring. He loved to attend their games and concerts, and continued his interest and support of their pursuits even after they left the house.

Patterson grew up fishing with his family in the Cook's Run area of Pennsylvania's Sproul State Forest and continued to travel there as an adult each spring for trout season, first with his nephews, then his sons, and on solo trips as well. Many will remember Patterson for his calm and quiet demeanor, but he was an active member of Cosmo's speaker's club at Edgewood Country Club, and never shied away from presenting an award, introducing a speaker or giving a toast. He will be remembered for his hearty laugh, his dry wit and his statistically impossible hole-in-one shot on Edgewood's number 3 in August 2006.

In lieu of flowers, you may honor Patterson's legacy with memorial donations to the Kanawha Valley Mining Institute Scholarship Fund, c/o The Greater Kanawha Valley Foundation, P.O. Box 3041, Charleston, WV 25331. ■



Gregory Douds Patterson

Colorado School of Mines

(continued from page 42)

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Recent rulings contradict stated mineral goals



William Gleason
Editor

In the spring of 2022 the Biden administration made a somewhat remarkable step of invoking Cold War era laws to boost production of a host of critical minerals that are needed for batteries for electric vehicles and other technologies that the administration viewed as being crucial to both a clean energy evolution as well as mineral independence.

At the time, it seemed as if the use of the 1950 Defense Production Act might be a catalyst for a mining boom in the United States. It directed the Defense Department to consider at least five metals as essential to

national security and authorized steps to bolster domestic supplies.

Domestic mining of such minerals could be a win on so many levels, it seemed. It could decrease the United States' dependence on foreign sources for important minerals. It could create high-paying jobs in states such as Minnesota, Alaska and Arizona where there are known deposits of copper, gold, nickel, cobalt, molybdenum ... many of the minerals the U.S. Geological Survey has included on its list of critical minerals. And, the mines would be put into production under the highest environmental and safety regulations in the world thus reducing minerals imported from unregulated regions where environmental and human-rights violations can often go unchecked. Seems like victories all around, right?

Maybe not.

On Jan 26, 2023 the Biden administration made the head-scratching announcement that it would withdraw more than 225,000 acres of land in northeast Minnesota from mineral development, including where Twin Metals had planned to develop its underground copper, nickel, cobalt and platinum-group-metals mine.

To remove the region from mining contradicts the stated goals of the administration. It is confusing and frustrating to see known deposits basically pulled off the table.

Secretary of the Interior Deb Haaland said that the decision was made to protect the environment near the mine. "With an eye toward protecting this special place for future generations, I have made this decision using the best available science and extensive public input," she said.

The day of the announcement, I spoke with Julie Lucas, executive director of

MiningMinnesota. Lucas, a strong advocate for responsible mining, doesn't agree with the best-science part. She told me, "The basis of this important decision is not based on sound science or careful study; instead, it is the result of political decisions informed by poorly constructed hypothetical scenarios. The same level of scientific scrutiny that industry is commonly held to does not apply to the federal government and that could not be more apparent than in the environmental assessment the Department of Interior is using to support this decision."

Rich Nolan, president and chief executive officer of the National Mining Association also had trouble making sense of the decision. In a statement, he said, "It's difficult to square the announcement of this significant land withdrawal with the Biden administration's stated goals on electrification, the energy transition and supply-chain security. At a time when demand for minerals such as copper, nickel and cobalt are skyrocketing for use in electric vehicles and solar and wind infrastructure, the administration is withdrawing hundreds of thousands of acres of land that could provide U.S. manufacturers with plentiful sources of these same minerals. In the end, by closing off more and more U.S. land to responsible domestic mining instead of producing minerals here at home, creating high-paying American jobs and mining operations that will be conducted in accordance with the world's most stringent environmental, labor and safety regulations, the administration is looking to stand up operations in the Congo and Zambia. It's nonsensical when you look at where the U.S. wants to be globally as a leader in manufacturing, innovation and climate."

A week after that decision, the U.S. Environmental Protection Agency potentially locked more minerals in the ground when it issued a final determination under the Clean Water Act that bans the disposal of mine waste in part of the Bristol Bay's watershed in Alaska, dealing another serious blow to the proposed Pebble Mine.

"This preemptive action against Pebble is not supported legally, technically or environmentally," said John Shively, chief executive of Pebble LP, a unit of Northern Dynasty Minerals Ltd., which has been working to develop the massive copper and gold mine in Alaska.

If it can't be grown, it has to be mined. The green energy future can't be grown, and if deposits are not permitted it won't be mined either. ■



Tunnel boring machine innovation TBM conversion at Mill Creek George Fox and Cutting Edge recap

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In This Issue

Tunnel boring machine (TBM) manufacturers like Robbins and Herrenknecht have been remanufacturing TBMs for decades. By putting the machines, or the main components, back to work contractors and owners can save money, time and reduce the carbon footprint of tunneling projects. On page 9, representatives from both companies talk about the benefits and challenges of remanufacturing TBMs. Cover photo courtesy of Herrenknecht.

Feature Articles



9 Benefits of remanufactured tunnel boring machines include cost and carbon savings

William Gleason



13 Unprecedented in-tunnel diameter conversion of the largest hard rock TBM in the United States

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The Cutting Edge: Innovation, new technology and moving the industry forward

There is an adage that goes: “If you do what you always did, you’ll get what you always got.” And while that may be a zone of comfort for some, history shows that it typically leads to stagnation, at best, and demise, at worst. Others might rally to the cry of “change and grow or die,” or “evolution is the natural progression.” Wherever you may stand in the spectrum, it’s hard to argue that innovation, in its many possible incarnations, has made the industry what it is today. Further, innovation has increased the competitiveness of tunneling with other alternatives such as those built on the surface or at elevation.

So, where do we go from here ... and how quickly?

It seems clear that the element of risk, particularly in terms of cost, is the primary headwind against innovation. I don’t think anyone necessarily innovates for the sake of it but rather because, with different approaches or implementation of new technologies, they visualize a better future state. One should always measure the potential benefit against what could go wrong ... but not be paralyzed by it. Fortune also reportedly favors the brave and, for some like the British Special Air Service, it becomes their motto (They who dare, win!). So, by all means, evaluate and mitigate risk but do not reject innovation. You will pay a price in the long term.

A decade ago, the UCA took the innovative step of partnering with *Tunneling Journal* and creating the annual Cutting Edge Conference, a forum conceived with the intent of showcasing novelty, innovation, current issues and future visions in the tunneling industry. I have had the privilege as Chair to be a part of the organizing committees of the last two conferences (2021 in



Michael Rispin
2022-2023 UCA Chair

Dallas, TX and 2022 in Long Beach, CA). The feedback received for this two-day, single-track forum has been overwhelmingly and effusively positive. If you have not yet attended, I encourage you to do so in 2023 and beyond. It feels like real momentum is building behind this event.

In 2021, it was my honor to moderate a panel, comprised of one owner, engineer, contractor supplier and academic, to discuss the state of innovation in our industry. We discussed how good or bad we thought we were, what obstacles needed to be removed to foster innovation, and how did we measure innovation and its effects. The discussion was brisk, with great input and perspective from the audience. While celebrating that the industry has moved forward, there was also acknowledgment that our industry tends to be a technology adoption laggard, that cut-and-paste specifications are completely counter to innovation and adoption of new technologies, and that owner bodies tend to be against things that have not been proven somewhere else.

Hey, somebody’s got to be first; and then there is the rush to lead the way to be second. In the 2022 conference, there was an engaging

(continued on page 6)

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BANGKOK FLOOD PROTECTION: AHEAD OF THE CURVE

The Bueng Nong Bon to Chao Phraya River Diversion Project is a major flood prevention tunnel being built in the capital as part of the Bangkok Metropolitan Administration's (BMA) long-term plan to manage flash floods.

Due to the dense urban environment, the tunnel's route has been dictated by the need to stay within public road easements, which has imposed a number of very tight radius curves on the alignment. To achieve these, TERRATEC has delivered two new 5.70m diameter tight radius EPBMs, which have been designed with an extreme X-type articulation system that can accommodate a minimum radius curve of 35m. Machine operation will be assisted by TERRATEC's highly-experienced Field Service staff to ensure optimum performance and successful project completion.

President Biden visits New York to announce \$292 million in funding for Gateway Tunnel

President Joe Biden announced a \$292 million grant to Amtrak to finish the Hudson Yards “tunnel box” concrete casing, a project that was started in summer 2013 to preserve the route of the Gateway Tunnel from Penn Station to the Hudson River as foundations were built for the Hudson Yards project.

The funding for the third and last phase of the tunnel box is from the National Infrastructure Project Assistance program, known as MEGA, which covers 50 percent of the costs of major construction projects of national or regional significance that otherwise would be too large or too complex to receive funding under traditional transportation programs. The program was announced last March.

The *Associated Press* reported that the \$292 million mega grant is part of \$1.2 billion in mega grants being awarded under the 2021 Infrastructure Investment and Jobs Act.

“We are looking at this as an early action construction project that will move ahead this year,” Eric Daleo, chief program officer and Megan Strickland, deputy chief program officer of the Gateway Development Commission said. “It is a critical

project that preserves a right of way and allows for development above ground and leads the other packages.”

The Hudson Yards Concrete Casing — Section 3 is one of nine nationally significant projects selected for this first year of the program out of 100 applications, U.S. Transportation Secretary Pete Buttigieg said in a statement. This grant will be funded over the course of four years from fiscal year 2022 to fiscal year 2025.

Another early construction project is at the Tonnelle Ave. Bridge. It was the first project that was undertaken 10 years earlier when the project was still called the Arch Project before it was canceled. Daleo said the Gateway Development Commission planned to issue a request for proposal for construction management and invitation for bid for services within a month for the Tonnelle Ave. Bridge.

The Gateway project will renovate the 1910 tunnel that is already carrying about 200,000 weekday passengers beneath the Hudson River between New Jersey and Manhattan, a long-delayed upgrade after decades in which the government underfunded infrastructure. The mega program is

expected to invest a total of \$5 billion through 2026 to help rebuild the nation’s infrastructure.

The \$16 billion Gateway Project to build two new rail tunnels and rehabilitate the existing 112-year-old tunnels has been pending since 2011. It took on greater urgency when a 2014 engineering report commissioned by Amtrak warned of deterioration from river water driven by Hurricane Sandy. Train capacity would be cut by 75 percent if one tunnel is shut down for a year to rehabilitate, Amtrak officials said.

“Building the Gateway Tunnel remains the tri-state’s most critical large-scale infrastructure priority,” Thomas Wright, Regional Plan Association chief executive officer said in a statement. “We applaud President Biden and his administration for recognizing the national economic significance of the project and supporting its advancement through one of the first major Infrastructure Investment and Jobs Act investments in the region.”

The project is being overseen by the Gateway Development Corp. New Jersey and New York will fund 50 percent of the cost under a 2022 agreement. ■

Tunnel contract for subsea tunnel in Norway awarded

A joint venture between Switzerland’s Implenia and Norway’s Strangeland Maskin has been awarded for the world’s longest and deepest subsea tunnel.

Implenia will take on the excavation and construction of an 8.6-km (5.3-mile) stretch of the Boknafjord tunnel, while Strangeland Maskin undertakes the construction of a 125-m (410-ft) section of connecting road, as well as the transportation of all excavated material, *Construction Europe*

reported.

Implenia said its activities amount to 80 percent of the contract, equating to a value of approximately €304 million.

Erwin Scherer, global head of tunneling with Implenia said, “We are excited to win such a major and prestigious project together with our JV partner Stangeland Maskin.

“The project E03 Boknafjord tunnel is a large and complex infrastructure project in line with our strategy, where we can contribute our many years of experience

and proven expertise in tunnel construction and related civil-engineering disciplines.”

The wider Boknafjord tunnel project comprises a 27 km (16.7 mile) long roadway, running below the huge Boknafjorden fjord in Rogaland in central Norway.

The responsibility of the Norwegian Public Roads Administration, the tunnel has seen a number of delays and cost increases and has a current completion date of 2033 and a budget of approximately €2.55 billion. ■

Tunnel boring machine for Brenner Base Tunnel ready to begin boring after completing test

Webuild and CSC announced that the Herrenknecht tunnel boring machine (TBM) named Lilia successfully completed the factory acceptance test and is ready to begin excavating one of the longest sections of the main tunnels of the Brenner Base Tunnel on Austrian territory.

The factory acceptance test was conducted at the Herrenknecht workshops at Schwanau in Germany. Lilia is one of the two TBMs that will be used to build Lot H41 Gola del Sill-Pfons. With its twin sister named Ida, with a cutting head more than 10 m (32 ft) in diameter, it will face approximately 8.2 km (5 miles) separating the assembly cavern, at the southern end of the lot.

The H41 Gola del Sill-Pfons, with an overall value of €651 million, was awarded to the Webuild Group last year in a joint venture with Implenia. Building the project will directly employ 400 workers. Webuild is

participating in the project with its Swiss subsidiary CSC Costruzioni, with an overall stake of 50 percent in the joint venture. The client is BBT SE, a European-listed company aimed at building the Brenner Base Tunnel, the railway line that will allow overcoming the natural barrier of the Alps between Italy and Austria.

The Brenner Base Tunnel measures an overall 64 km (40 miles) becoming the world's longest railway tunnel. It is one of the most significant priority infrastructure projects currently being built in Europe, a junction of the European SCAN-MED (Scandinavian-Mediterranean) corridor.

Lot H41 foresees a section of the Brenner Base Tunnel in Austria and consists of the construction of the railway from Gola del Sill near the city of Innsbruck in the north to the town of Pfons, located further south. It will excavate 22.5 km (14 miles) of main tunnels and 38 transversal

underground passages with an overall length of approximately 2.3 km. The tunnels that have already been excavated in previous lots will also be lined, as well as the underground emergency stop at Innsbruck, the access window, the explorative tunnel and other portions of secondary tunnels.

The construction project of Lot H41 started in January 2022. Currently, the excavation activities of the assembly caverns present in the emergency stop of Innsbruck and building the partition wall of the interconnection tunnels are being carried out.

Webuild is already working on the Isarco Underpass and Mules 2-3 lots of the Brenner Base Tunnel. In Austria, it has already built the Tulfes-Pfons Lot. Webuild is also committed to building the southern access sections to the Brenner Base Tunnels, between Fortezza and Ponte Gardena. ■

TBM named Diggy Scardust launched in Toronto

It has been more than nine years since the Toronto City Council approved the Scarborough subway extension project and now construction has begun.

The tunnel boring machine (TBM) named "Diggy Scardust" was launched in January. Metrolinx officials have said that the machine will create a single subway tunnel with a diameter of 10.7 m (35 ft), which will be large enough to accommodate trains traveling in both directions.

The TBM will advance about 10 m (33 ft) each day, officials said, with crews using a belt conveyor to transport soil and rocks back to the launch shaft site, CP24 reported.

"Today, we have hit another major milestone in delivering this much-needed project. Diggy

Scardust, the largest tunnel boring machine ever used for a transit project in Canada, has started tunneling," a spokesperson for Minister of Transportation Caroline Mulroney told CP24.

The 7.8-km (4.8-mile) subway extension is likely still years away from completion with the latest timeline suggesting that it won't be operational until 2030.

The project is expected to host 105,000 daily boardings, including 52,000 by new users. The project will include improved access to transit and jobs while reducing yearly gas emissions by 10 kt (11,000 st).

The City of Toronto has said that it will shut down the Scarborough RT next fall due to the significant costs associated with maintaining the aging rapid transit line.

A portion of the Scarborough RT's right-of-way will be turned into a dedicated busway to help provide supplementary service until the completion of the subway extension.

But that project could take until late 2025 to complete, according to the Toronto Transit Commission (TTC).

The Scarborough RT opened in 1985. It was initially supposed to be replaced by a light rail transit network that would have been completed in 2020 but that project was canceled under the leadership of former Mayor Rob Ford in 2010.

The Ministry of Transportation said that the new Scarborough subway extension will accommodate more than 100,000 daily trips once complete. ■

Chair's column: Innovation drives us forward

(continued from page 2)

panel of owners, with four representatives willing to sit and comment on tunneling from their perspectives, and to entertain questions from the audience. It was asked whether owners would be supportive of first-time innovation on one of their projects. One respondent stated confidently that if it was in respect to means, materials and methods, they would, provided a requisite risk analysis had been completed. A second panel member had a different take with the response being along the lines of "we can only do so much," elaborating that there would be reticence to try things that were not already applied elsewhere.

Contractors tell me that they want to innovate more, particularly where efficiency, cost and/or safety benefits can be realized on their projects at-hand, but that their hands get tied if it is something "new." Engineers may be open to evaluating new technology, but somewhere

between avid interest and convincing their client that it is the way to go, enthusiasm gets lost. Suppliers, while happy to provide the tried-and-true, also keenly understand the need to innovate or their business will suffer when the next best mousetrap comes along from a competitor. But there also must be a receptive audience. Does this illustration strike a chord for anyone?

All industry participants have a part to play. Coming full circle, where do we go from here? It seems that in terms of stakeholder awareness (infrastructure owners, society-at-large), our industry is in



the public eye more now than ever. We have the opportunity to show how the tunneling and underground construction industry has innovated and got us to where we are now. We also have a burden to continue innovating, enabling the building of safer, bigger and better underground infrastructure, in lieu of alternatives at the surface.

Tunnel on! ■

Webuild wins rail bypass contract in Trento, Italy

Construction consortium Webuild and its partners announced that they have won a €934 million contract from Rete Ferroviaria Italiana (RFI) of state rail operator Gruppo FS Italiane for a rail bypass at Lot 3A of a project in Trento, Italy.

Webuild, which has a 55 percent stake in the consortium, will lead the design and construction of approximately 13 km (8 miles) of rail line, nearly all of it underground, as part of a quadrupling of the Fortezza-Verona section of the high-speed railway south of the Brenner Base Tunnel.

The contract is designed to create approximately 1,000 jobs, directly and indirectly, with significant involvement from the supply chain.

Webuild's consortium partners include Ghella with 35 percent and

Collini with 10 percent. Webuild has a 51 percent stake with subsidiary SELI at 4 percent.

Lot 3A, which has been identified as a strategic project for the development of sustainable mobility in Italy under the National Plan for Recovery and Resilience, will contribute to improving the international transport of cargo and the improvement of the country's competitiveness. The rail line belongs to the strategic Munich-Verona corridor, as well as a broader program to upgrade transportation services in Trento such as the bypass, which is expected to reduce more than 65 kt (76,000 st) of carbon dioxide every year.

The contract includes the construction of a natural tunnel — the Trento Tunnel of approximately 10.6 km (6.6 miles) in length — and

two short sections above ground alongside the existing line. Four tunnel boring machines (TBMs) will be deployed to excavate the tunnel with two working at either end of the projected tunnel. The rate of excavation is to reach between 15 and 20 m/d (50 to 65 ft/day), helping accelerate the work.

The bypass — known in Italian as the "Circonvallazione di Trento" — will be part of the southern access to the Brenner Base Tunnel.

Webuild is working on three of the five sections, or lots, of this tunnel: Mules 2-3 and Isarco River Underpass in Italy, and Gola del Sill-Pfons in Austria. The group has completed Lot Tulfes-Pfons in Austria, while working on the Fortezza-Ponte Gardena access line in Italy that is also part of the Munich-Verona corridor. ■

Final tunneling contract for Sydney Metro West infrastructure project awarded

The third and final major tunneling award of the Sydney Metro West infrastructure project in Sydney, Australia was awarded to the John Holland, CPB Contractors (CPB) and Ghella joint venture (JCG JV).

The tender process for the Sydney Metro West tunnel began in April 2020 after the project to create 24 km (15 miles) of metro rail tunnels from Westmead to the Sydney central business district (CBD) was announced in 2017.

When the project opens in 2030,

the project will double rail capacity between greater Parramatta and the Sydney CBD, while also connecting new communities to rail services.

Valued at A\$1.63 billion (US\$1.09 billion), the contract includes a tunnel boring machine (TBM) launch site at The Bays, 3.5 km (2.2 miles) of tunnels from The Bays to the Sydney CBD, a turnback cavern to the east of the new Hunter Street Station, and excavation and civil works for two new cavern stations at Pyrmont and Hunter Street.

Sydney Metro reported that two TBMs will be used to tunnel from

The Bays toward Hunter Street, with preparations scheduled to begin in 2023.

Early 2023, construction of the twin tunnels between The Bays and Sydney Olympic Park and between Sydney Olympic Park and Westmead will also begin.

In preparation for this work, the project's first two TBMs arrived at The Bays Station site in October.

These machines include refurbished parts from those used on the Sydney Metro City and Southwest project, scheduled to open in 2024. ■

Sandvik to supply tunneling machines to Australia

The New South Wales government, Tansurban and M7 Westlink shareholders have awarded Sandvik a contract to supply tunnel machinery for the construction of the NorthConnex project that will link M1 Pacific Motorway at Wahroonga to the Hills M2 Motorway at West Pennant Hills.

WorldHighways reported that Sandvik will supply 13 of the 19 road headers.

The machine supply deal was made by the Lend Lease-Bouygues joint venture to Sandvik Mining and Construction Australia. The order includes six of the large MT720 units, one MT620 model and six of the MT520 units. This represents the largest single order for Sandvik tunneling road headers since it received an order for the Sochi

Olympic Park excavation more than five years ago.

The project is of strategic importance for New South Wales and is designed to help cut travel times and traffic congestion in and around Sydney. This new route will link Sydney's north to the Orbital network and form part of a national highway route when complete.

The project includes driving twin motorway tunnels, each measuring 9 km (5.6 miles) long. The tunnels will have two lanes and a breakdown lane in each direction, as well as a height clearance of 5.3 m (17 ft) with a speed limit of 80 km/h (50 mph). The project is estimated to cost approximately US\$3 billion in total and will be Australia's longest road tunnel when the link opens to traffic.

The Lend Lease-Bouygues joint

venture (LLB JV) was originally formed to construct the East-West Link project in Melbourne and NorthConnex. The joint venture was the successful bidder on both projects, but following the cancellation of the East-West Link project the focus switched to NorthConnex. Lend-Lease is globally operating the Australian construction company, and Bouygues is one of the largest construction companies in the world with headquarters in France. The joint venture is a 50-50 partnership.

Mechanical cutting with roadheaders was selected as the most suitable excavation method for NorthConnex. This was due to the large number of different tunnel profiles (intersections, ramps, shafts) in the project scope, and the accurate excavation profile required. ■

Biden administration visits Potomac Tunnels

President Joe Biden met with rail officials managing the Baltimore and Potomac Tunnels in a push for the long-awaited overhaul of the aging infrastructure of this busy corridor connecting Baltimore and Washington, DC. Biden was there to

champion the \$1 trillion bipartisan infrastructure legislation and the anticipated massive investment in fixing roads and tunnels throughout the United States.

The project is expected to take roughly a decade and will have two tubes with up to four tracks

total, allowing trains to travel at more than 100 mph. The total project including related bridges and equipment modernization is anticipated to cost \$6 billion.

Baltimore was the first of three stops related to infrastructure that President Biden visited in February. ■

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Benefits of remanufactured tunnel boring machines include cost and carbon savings



This Robbins TBM was originally built in 1995 and has been used on six tunnels around the world including in Laos, Mexico and most recently at Ashbridges Outfall in Canada.

The practice of remanufacturing or refurbishing tunnel boring machines (TBM) is not new to the tunneling industry. Tunnel project owners and contractors have often turned to TBM manufacturers for “used” machines for many years, and for a variety of reasons.

However, the term “used” can be a bit misleading when it comes to TBMs. Rarely is an entire machine pulled from one project and put to use at another project. The diameter of each tunnel often changes as do the requirements for the TBM. And the ground conditions of each project is always different from other projects.

“It comes down to the ground conditions and unless it is parallel tubes, no two projects experience

the exact same ground conditions. That is the nature of our business. Even if the diameter of the tunnel stays the same, which is rare, everything that is related to the ground interface such as the cutter head or mucking system has to be optimized to the ground conditions of the specific project,” Werner Burger, chief engineer at Herrenknecht said.

Because of this, larger and more complex TBMs are rarely used in their entirety; however, the main components of a TBM, such as drive systems, man locks, large hydraulic cylinders, erector, powerpacks, gantry components, or main structural components can be remanufactured and given an entirely new life cycle. And these tried-and-true components often provide as much or better success than a new machine.

Brad Grothen, vice president-engineering of Robbins told *T&UC* that his company has been in the practice of rebuilding TBMs for decades.

A case in point is a main-beam TBM that was

William Gleason, Editor

originally built in 1995 and has been used on six tunnels around the world. “At its three most recent tunnels, it has been refurbished as an 8.7 m (28 ft) diameter, single-shield TBM at Theun Hinboun Expansion Project in Laos, start date 2009; as an 8.7 m (28 ft) diameter, crossover XRE TBM at Tunel Emisor Poniente II in Mexico, start date 2015; and as a 7.96 m (26 ft) diameter, single-shield TBM for the Ashbridges Bay Outfall Tunnel in Canada, start date 2019,” said a Robbins spokesperson.

Likewise, Herrenknecht is committed to getting the most out of its machines. The company offers a buy-back program for its machines and has a worldwide unique plant that extends more than 100,000 m² in Kehl, Germany dedicated to the remanufacturing and refurbishment of components. Olaf Kortz manages the facility and explained to *T&U* that Herrenknecht’s process closely follows the International Tunneling Association’s (ITA-AITES) ITAtech group guidelines “ITAtech Guidelines for Rebuilds of Machinery for Mechanized Tunnel Excavation” that were first drafted in 2014-15 and revised in 2019 to include computer and guidance systems. Accordingly, Herrenknecht is quite clear about the distinction between refurbishment and remanufacture: refurbishment allows the part to be used for the rest of its design life, or to extend the original design life to some extent, whereas remanufacturing re-engineers the part to the beginning of a new life cycle. According to the ITAtech guidelines, remanufacturing does not take place on the jobsite due to the required special equipment.

Herrenknecht remanufactures components at its plant to be certified to be as good as new, including updates to the latest technical standards. Over the past decade the company has had numerous machines and components return to action.

Why choose a refurbished machine

In a paper titled “Rebuilding TBMs; Are used TBMs as good as new?” presented at the Rapid Excavation and Tunneling Conference (RETC) in 2019, Doug Harding of Robbins wrote that for years, the advantage of using a refurbished TBM versus a new machine built specifically for a job was based on economics and time. The costs can vary from as much as 75 percent for a simpler machine on a project with tried-and-tested ground conditions to around 20 percent for a project with more complex requirements (Harding, 2019). A refurbished machine can also represent significant savings in terms of time. A refurbished machine can sometimes be ready in a matter of months while it might take more than a year for a new



One of the three Herrenknecht TBMs used at the Washington Clean Rivers Project. Herrenknecht remanufactures TBMs at its plant in Kehl, Germany.

TBM to be manufactured.

“As long as the TBM is well maintained, there will be jobs it can bore economically,” Harding wrote in the 2019 RETC paper. “Optimal TBM refurbishment on a used machine requires a broad knowledge of the project conditions, and there are some limitations: Machine diameter can be decreased within the limits set by free movement of the grippers and side/roof supports; machine diameter can be increased subject to the structural integrity of the machine and the power/thrust capabilities, and propel force can be increased only to the level supported by the grippers’ thrust reaction force.”

Carbon savings

For manufacturers such as Robbins and Herrenknecht as well as tunnel project owners and contractors,



Herrenknecht estimates that on average, as a result of the remanufacturing process per ton of components, 71.42 percent of the emissions are saved compared to the production of new components.

remanufactured TBMs or TBM components often make good business sense. Recently, the additional factors of sustainability and carbon savings have gained more attention as well.

Tunnels and underground infrastructure, by their very nature, provide solutions to many urban growth challenges, including climate goals, such as reducing carbon emissions from tunnel projects. While mass transit tunnels are one of the most efficient ways to reduce road traffic and the carbon emissions from automobiles and freight trucks, the construction of a tunnel is a carbon-intensive process and many owners are facing increasing pressure to reduce the carbon footprint of each tunnel project.

In many public tenders for tunneling projects, environmental criteria are now standard, and it is expected that in many countries this trend will continue and environmental regulations will continue to tighten.

Grothen said that Robbins has seen demand for completely new machines and components wane as project owners realize the sustainability benefits of remanufactured components and machines.

Herrenknecht has calculated that “on average, as a result of the remanufacturing process per ton of components 71.42 percent of the emissions are saved compared to the production of new components.” And in Herrenknecht’s calculation this includes carbon dioxide (CO₂) emitted during the transport of components from the jobsite to Kehl.

According to Kortz, with a completely

remanufactured tunnel boring machine the energy savings are about 80 percent. In addition, when compared to a new machine, about 99 percent less materials have to be used. This is a huge saving that conserves resources, reduces CO₂ emissions and improves the environmental balance of the machine — and thus the entire construction project.

In addition to the sustainable benefits from reused parts, there can be a significant savings in transportation of components.

“Remanufacturing components and TBMs is a big part of our business,” Grothen said of the Robbins process of refurbishing TBMs. “I think the challenge comes as you look at what gets refurbished. It is always tricky — its price and carbon footprint — and when you consider refurbishment, the shipping of big, heavy pieces of equipment is also a huge cost and carbon producer.

“When you do the refurbishment you have to consider where you are going to do the work — onsite or back at the factory,” said Grothen. “The location is important and for shield machines like an open main-beam machine, you don’t have many pieces touching the tunnel wall so slight changes in diameter are not so detrimental, but when you look at a shield machine it is more difficult to change diameters. They are designed more around the segment of that project so unless there is standardization of the segment it is more difficult to reuse the outer shield of the TBM and all the weight that goes with the shield. So machine type really matters and where you refurbish it.”



For Robbins, remanufacturing components of tunnel boring machines has been a common practice for decades. It can save money, time and reduce the carbon footprint of a tunnel project.

Available equipment

Because TBMs are more like a mobile factory than an individual machine, inventory is a challenge.

Some TBMs are moved around the world, while others can stay in the same region. Grothen said that some regions of the world have tried to create a standardized segment lining for certain types of tunnels. This makes it easier to repurpose TBMs for tunnels with the same diameter and helps with the issue of inventory; however, changing ground conditions remain a challenge.

“I have never found two jobs with identical ground conditions,” Burger said. “A project in its early design is maybe 10 years out, so knowing which machine might be available is difficult. When a project is in the design phase there are informal contacts but hardly ever a situation that a project is designed for an existing TBM. What could help in the future would be if there are specs in the bid process that indicate a range of flexibility for the machine or the tunnel. For example, for a water tunnel, if it has a diameter that is 4 inches larger than the specs it doesn’t really change the tunnel, but it could open the door more to bring in existing equipment.”

Next steps

Much of the programming at the 2022 Cutting Edge Conference presented by UCA and *Tunnelling Journal* was dedicated to sustainability in the tunneling industry (see page 23). Project owners, contractors and engineers

are facing increasing pressure to not only convince outside stakeholders that their tunneling project will be a net positive for the community in which it is built, but to reduce the carbon footprint of building the project.

Innovation and technology will be needed to carry the industry forward.

“We now have more digitization in the machines including artificial intelligence (AI), and this contributes to optimized energy and efficient use of the machines,” said Burger. “These technologies give the operators advice by telling them which motor could be switched off or even having automated systems determine the amount of energy needed. Downsizing of machines could be an option as well, but we would still need to know the ground conditions. There is a compromise of having sufficient power installed to overcome the unexpected but not oversteering.”

Burger said that in the next decade he expects to see more technology incorporated to help TBMs become more efficient in their use of power and fuels.

“For the future I think we need to consider not just one element of the tunneling process but to look at the complete tunnel operation from the project design all the way through equipment and materials,” Burger said. “There is a potential to bring the industry forward in the direction of more sustainable solutions. This will need the cooperation of all involved parties starting with the owners to the equipment supplier.” ■

Unprecedented in-tunnel diameter conversion of the largest hard rock TBM in the United States

The Mill Creek/Peaks Branch/State-Thomas (MCPBST) Drainage Relief Tunnel is a 5-mile (8-km) underground tunnel that will provide flood protection for the east Dallas, TX area. The project required a drainage tunnel starting at a diameter of 11.6 m (38 ft) and ending with a diameter of 9.9 m (32.48 ft). The upstream 5.2 km (3.23 miles) are designed with a circular cross section for a peak flow of 425 m³/s. The downstream 2.8 km (1.74 miles), running between the outfall shaft to the East Peaks Branch intake (Fig. 1), was originally designed with a horseshoe cross section to allow a higher peak flow of 566 m³/s. The horseshoe section was to have been excavated by the tunnel boring machine (TBM) initially and expanded by roadheader to create a flat invert. Two different sets of formwork would also have been required to cast the final lining for both the round and horseshoe profiles, making the process potentially time consuming and costly (Rowland, 2019). Because of the cost and time to excavate by roadheader, one TBM was selected instead.

A Robbins rebuilt TBM along with a continuous conveyor (including a vertical conveyor) was chosen as the boring system. During early project discussions with the machine supplier, a decision was made to reduce the boring machine diameter in the tunnel, lowering project costs and reducing the construction period (see Fig. 2).

FIG. 2

The 11.6 m (38 ft) diameter Robbins main-beam tunnel boring machine (TBM) at launch. It is the largest hard rock TBM ever used in the United States.



FIG. 1

The 8-km (5-mile) route of the Mill Creek Drainage Relief Tunnel.



Without a prepared chamber, in situ diameter changes raised the number of challenges encountered. The changeover was designed and conducted in three distinct parts, with each presenting its own difficulties and corresponding opportunities to be collaboratively solved:

- The TBM proper.
- The trailing gear.
- The tunnel conveyor system.

TBM reduction

The TBM story begins with the design phase. Working with a rebuilt machine, the designers started with the concept to build a smaller machine and then install a wrap to make the larger diameter. It was hoped this way would reduce the difficulty inherent in the diameter reduction. Several items taken into consideration included:

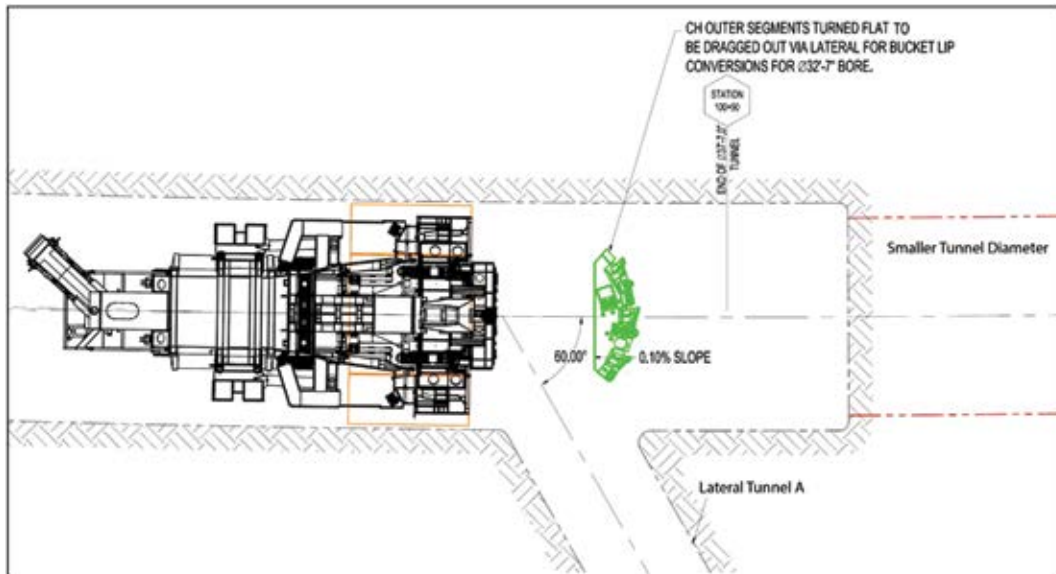
- Cutterhead segments and how to handle them.
- Thinking ahead with skin-weld placement with

Steve Chorley and Evan Brinkeroff

Steve Chorley, member UCA, is vice president operations, and Evan Brinkeroff is site manager, Robbins. Email chorleys@robbinstbm.com.

FIG. 3

The tunnel boring machine plan view in relation to lateral tunnel A at diameter change site.



- respect to interior accessibility.
- Thinking ahead about gripper-shoe wraps.
- Adjustability of the drills.
- Ground support platforms and associated extensions.

The original strategy was to excavate to the transition station, back the TBM system approximately 22 m (72 ft), change the diameter, then commence boring at the smaller diameter while adding conveyor parts to adapt to the new diameter. During the initial design phase, the

concentricity of the two diameters was discussed, and it was decided that the two tunnels should be concentric. A communication misunderstanding led to the conveyor system beginning component construction understanding the two tunnels to be eccentric — a fortuitous misunderstanding, as we shall see.

As per the contract requirements, the ground support consisted of rock bolts spaced 1.5 m (5 ft) apart longitudinally, along with woven wire fabric, and crown straps as needed. Additional bolts, straps and mesh were to be installed as needed. Part of the transition plan was

FIG. 4

Cutterhead diameter change sequence.

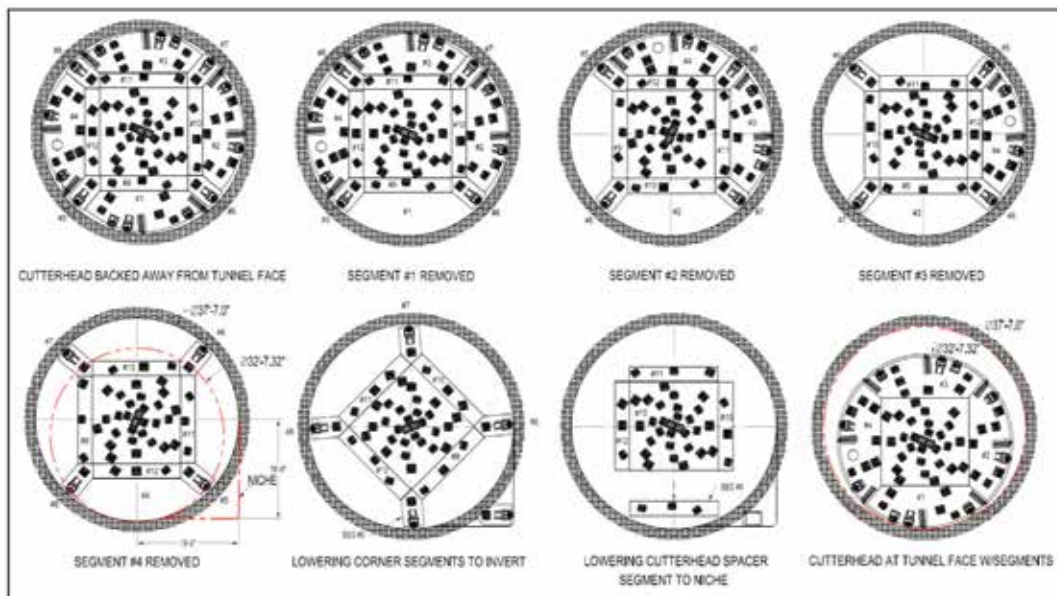


FIG. 5
Cutterhead segments being removed in the lateral access.


to back the TBM approximately 22 m (72 ft) leaving cutterhead sections behind; upon arrival at the transition the ground turned bad — the crown became loose rock and required additional rock support that could not be removed, thus obviating the required back up as the entirety of the work had to be done from supported ground. The straps and bolts protruded into the TBM envelope even with the roof support fully retracted, so another solution was needed. The contractor, Southland Holdings, and Robbins Co. personnel put their heads together and found a solution that required only backing the head a mere 76 cm (2.5 ft). The process would be achieved by removing cutterhead sections and other pieces through lateral tunnel A, a 6 m (19.6 ft) diameter, 90 m (295 ft) long, horseshoe tunnel built using excavators and hydraulic hammers. The lateral tunnel connects with drop shaft A, at 52 m (170 ft) deep and 6 m (19.6 ft) in diameter. The arrangement allowed personnel and equipment to access and begin the conversion process through the lateral tunnel, and remove pieces on rails through the shaft and up to the surface (Fig. 3).

The reduction took place from the front of the machine starting with the cutterhead and ending with the conveyor. The cutterhead was designed to have four spacer segments installed between the cutterhead center section and the outer sections, with four small, intermediate sections filling in the gaps at the so-called corners (Figs. 4 and 5).

The team dismantled and removed the four cutterhead sections, the four intermediate sections, and the four spacers from a lateral tunnel, lateral A, which intersected the main tunnel precisely at the diameter change. The heaviest section weighed just over 15,000 kg (33,069 lb) and given the small access window, required planning to maneuver the pieces out of the lateral access to the surface for refitting for the small diameter, and returning to the installation position.

Working from the lateral tunnel, the welds securing the intermediate spacers were removed through the buckets. The team made the decision to remove the spacers in sections, cutting them from the lateral, leaving the mounting flanges in place. The spacers were then pulled from the cutterhead in sections.

The crews were then able to remove the cutterhead sections entirely from within the safety of the confines of the cutterhead and the lateral access. Working on the bottom section and from within the cutterhead, the crews then removed the fasteners and allowed the cutterhead section to rest on the invert. As the TBM was not retracted, the cutterhead sections settled in the invert nicely as they waited to be removed. To facilitate the cutterhead section removal, the cutterhead drive motors, controlled via variable-frequency

drives, were used to rotate the cutterhead and push the first cutterhead section out through the lateral where it could be collected and sent to the surface.

The cutterhead was then rotated 180° and the process was repeated, removing the next cutterhead section. After the first two sections were removed, the process was repeated until all the sections were removed. The next step was to remove the cutterhead spacers.

The spacer fasteners were removed from within the cutterhead. To control the lowering of the spacers, hydraulic jacks and spacers were used to lower each

FIG. 6
Transition area showing the roof shield skins and transition area from the top.


FIG. 7

TBM roof shield skin removal.



section in a controlled manner once the fasteners were removed.

The rest of the TBM, trailing gear and conveyor work was accomplished while the cutterhead sections were being refurbished. When the cutterhead sections were returned, they were installed using the jacks and spacers that were used to remove the spacers. A dedicated transport sled was fabricated to facilitate the positioning and lifting of the spacers to the cutterhead

FIG. 8

Installation of the smaller-diameter cutterhead structure.



center section.

Working from within the shield skin the crews removed the outermost skins from the roof supports and side supports. The crews then fashioned chain action rollers supported by hydraulic jacks to maintain roof support pressure against the crown, especially as the TBM advanced until the front of the roof support skin could be secured in the crown with rock bolts and straps. The roof support skin and roof support extensions were secured in place using rock bolts and crown straps (Figs. 6 and 7).

As part of the planning phase, it was thought that the smaller-diameter roof shield extensions would be too unwieldy to maneuver within the confines of the tunnel. With minimal overhead clearance, just 76 cm (2.5 ft), it was thought that hoisting a heavy-shield extension from the invert up and around the main beam would be too great an obstacle. The solution was to cut the smaller-diameter roof support extensions into three smaller pieces and weld them in place on the roof shield extensions. It was then just a matter of sliding the precut pieces into position and completing the welds. During the excavation of the larger diameter there were a few inconveniences but they were insignificant to the larger picture.

The vertical front support did not need to be removed from within; the crews needed only to remove the fore and aft welds to free the small-diameter TBM and allow the TBM to push off the vertical front support when the time came. The crews carefully fashioned the side support skins and reinforcing ribs into supporting members for the gripper shoe skins. The gripper shoe skins were positioned carefully onto the side support skins and welded in place. A few rock bolts were installed into the side supports to ensure they did not shift as the TBM passed through, and crews worked closely in, on and around them. Once the cutterhead was reassembled the TBM started mining forward (Fig. 8).

This phase of the transition required many steps to remove the accumulated material from in front of the vertical front support. Mining with a concentric tunnel meant there was a 76-cm (2.5-ft) step between the two bores and the rock would accumulate and prevent the TBM from advancing until it was clear. Once the vertical front support was abutted to the transition step, the aft welds were removed and mining began again, with the TBM sliding from the vertical front support and into the new-diameter, freshly bored tunnel. The gap between the vertical front support and the newly bored tunnel was about 7 to 10 cm (2.75 to 3.9 in.), and this gap was mostly filled with accumulated material from the mining operations and presented no difficulty.

Concurrent with the TBM advancement, permanent roof support anchors were installed to secure the shield skins to the tunnel wall. The temporary chain rollers and supports were then removed.

Once the TBM was excavating at the smaller

FIG. 9

The gantry lift process.


FIG. 10

The completed diameter transition area.



diameter, the crews cut the shield wrap inner reinforcements into manageable size parts and removed them on a flat car, leaving the skin plate in place. The contractor was granted a variance to leave the roof support skins and skin extensions secured to the crown. These will be cast in place during the lining of the tunnel.

With the TBM beginning to advance at the small diameter, the next part of the transition was the gripper shoe extensions. This again highlights where the planning phase is of utmost importance. During the side support extension removal phase, consideration was given to the gripper shoes as they passed the transition area and carefully laid out cuts were made to the side support wraps and re-enforcing ribs such that the gripper shoe extensions would lay neatly in place supported by the cutouts. The gripper shoe extensions were then welded in place to the side support extensions with a couple of rock bolts securing the tops of the extensions.

After the gripper shoe extensions were laid into the side support cutouts, the remaining welds holding the extensions to the shoes were removed. The TBM then began a regrip cycle with a noteworthy additional step. Just prior to the gripper shoes rear half being placed on the forward part of the gripper shoe extensions, the voids in the extensions were filled with sandbags to allow the gripper to apply full force to the tunnel walls. The sandbags prevented the supporting members of the

wrap from racking under the propel and gripping forces.

The final item for the TBM reduction was the rear support shoe extensions. These were abutted against the rear of the vertical front support and then the extensions were removed; the next boring cycle brought the shoes to rest fully upon the vertical front support.

The trailing gear reduction was neatly taken care of during the design phase. Instead of reducing the diameter of the trailing gear, a smaller-diameter trailing gear was used with extensions on the wheel bogies to bring the trailing gear to the correct elevation when the TBM was 11.6 m (38 ft) in diameter. All that remained at the diameter change was to remove the wheel bogie extensions and position the trailing gear in the small diameter. There were a few platforms that had extensions upon them that needed to be removed, but they were minor and handled as needed.

The original design was to lead the trailing gear up a two percent slope requiring a substantial amount of civil works to build the ramp between the TBM and the first gantry of the trailing gear. There was not much space within which to work, so this design was not desirable. The bad ground encountered at the diameter change station eliminated the ability to back the TBM more than absolutely necessary. There were several discussions held in an effort to find a workable solution, and ultimately the contractor and Robbins decided a novel approach would work. The decision was to use rented hydraulic cylinders in conjunction with fabricated

spacers and raise the entire trailing gear at the same time. This decision naturally created obstacles, but these were overcome (Fig. 9).

While the gripper shoe extensions were being removed, the crews installed fabricated supports to the tunnel walls upon which were placed hydraulic jacks. Four jacks were used per gantry with each gantry having a dedicated pump and each jack having a dedicated isolation valve. During the lift, crews took careful measurements to ensure the trailing gear raised at the same rate and at no point were any two jacks allowed to become more than 3 mm different in extension, thereby ensuring the entire trailing gear lifted equally. (Each jack had a maximum capacity of 45 t (50 st), so with the maximum weight of the heaviest gantry at 61,700 kg, the job was done with a generous safety factor.)

As the gantries were lifted, spacers were inserted as an extra measure of safety until all four gantries were lifted to the correct elevation. The wheel bogies were removed and spacers were installed to the gantries and the bogies installed to the spacers. The gantries were then lowered until the weight was borne by the bogies and mining resumed.

When the leading bogie for the first gantry reached the abandoned vertical front support, mining was paused and the front of the first gantry was raised enough to install the same continuous chain rollers used for the roof support. They were installed onto spacers welded to the vertical front support and then the gantry was lowered onto the chain rollers such that the weight of the front of the gantry was borne by the chain roller. The leading bogie and extension were removed from the front of the first gantry and mining resumed. When the

TBM had pulled the trailing gear sufficiently far, mining was once again paused. The front of the first gantry was again lifted, the chain rollers removed and the bogie (without extension) was reinstalled. The gantry was lowered and mining resumed.

This process was repeated until all the trailing gear was inside the newly mined tunnel (Fig. 10).

The tunnel belt also had to be transitioned to the smaller tunnel diameter.

- The transition occurred in a curve just after the first carry booster was scheduled to be installed.
- Due to a collaborative misunderstanding, the TBM division knew the tunnel was concentric while the conveyor division thought it was an eccentric tunnel.
- Originally a carry booster was designed to be installed a few hundred feet into the smaller-diameter tunnel, this required a substantial elevation correction to the tunnel belt to allow space between the carry belt and return belt to fit the booster rollers.
- The elevation difference was 76 cm (2.5 ft) on the radius, the installation of the first carrying booster was 91 cm (2.9 ft) — a fortuitous coincidence. The decision was made to postpone the installation of the carrying booster while excavating the wall for installation until the belt elevation only required 15 cm (0.49 ft) of transition.
- After the TBM and trailing gear passed through the transition diameter phase the team used a remnant of the large-diameter shield as a

TABLE 1

Ground support requirements based on rock mass classification.

Rock mass class	Description of ground conditions	Rock mass rating	TBM production (m/h)	Ground support	Rock bolt type	Installation time (approximate)
Type I	Very good	81-100	1.5-3.2	Generally no support required, only spot bolts.	Mechanical anchor/split set friction bolt	≤3 mins per bolt
Type II	Good	61-80	2-3.5	Local bolting with occasional mesh.	Mechanical anchor/split set friction bolt	≤3 mins per bolt
Type III	Fair	41-60	1.1-1.5	Systematic bolting with wire mesh in crown.	CT bolt resin anchored bolt	3 to 5 minutes per bolt
Type IV	Poor	21-40	0.8-1.1	Systematic bolting with wire mesh crown on side walls. Light steel ribs and local shotcreting.	CT bolt resin anchored bolt	Depends on length of hole to be drilled and exposed ground condition.
Type V	Very poor	<20	<1	Systematic bolting with wire mesh over crown and side walls. Heavy steel ribs and shotcreting.	CT bolt resin anchored bolt	Depends on length of hole to be drilled and exposed ground condition.

mounting base upon which to install the first of five tunnel belt boosters, in this case a 375-kW dual motor carrying booster.

The conveyor booster installation was relatively easy and was carried out in a timely manner.

Overall, the diameter change process took about four months to complete — the revised setup backing the machine up by only 76 cm (2.5 ft) saved about one month compared to the originally devised plans to excavate a transition station and back the machine up 22 m (72 ft). The ground conditions, particularly poor rock quality in the crown, dictated the change in plans, and was ultimately highly successful.

Ground conditions and TBM performance

The TBM at Mill Creek is well equipped for rock bolting with dedicated rock drills mounted on a ring gear allowing for installation of rock bolts in the needed areas of the tunnel. Table 1 gives a general overview of rock bolt types that may be considered in relation to rock mass classification. (It should be noted that ultimately the decision on which type of rock bolt is to be used should be made on a case-by-case basis.)

The Mill Creek machine is operating in Austin chalk and Eagle Ford shale with a compressive strength between 17 and 30 MPa. The requirement for systematic rock bolting is in part due to the rock being classified as mainly Type III and some areas of Type IV conditions. In Type IV conditions, the contract called for eight additional rock bolts, resulting in 76 cm (2.5 ft) linear spacing with wire mesh covering the crown and steel straps as needed. Once through the learning curve, the crew began installing eight bolts in the Type III conditions within 20 to 25 minutes (Fig. 10).

Probing is also required to 60 m (196 ft) in front of the machine in every 46 m (150 ft) of mining, thereby providing a safe zone of 15 m (49 ft) ahead of the machine. To date, there have been no significant water inflows into the tunnel.

Due to the required systematic approach to production, the machine is currently averaging approximately 16 m (52 ft) advance per day. Limiting factors to production are the probing requirements and the capacity of the vertical conveyor. At the time of this writing, the machine has achieved some impressive performance results:

- Best day: 41 m (134 ft) (at the 11.6 m (38 ft) diameter)
- Best week: 118 m (387 ft)
- Best month: 498 m (1,633 ft)

At the current rates of advance, boring is scheduled to be completed in June 2022.

Due to the relatively favorable ground conditions in

much of the tunnel, including low rock strength and low abrasivity, only eight cutters were changed during the length of tunnel bored at the larger diameter. At the time of diameter change, the full dress of cutters was changed. As in the larger diameter tunnel, cutter inspection times and the downtime associated with them are limiting and are generally only carried out when trouble is suspected.

Conclusions

Construction sites can be contentious working environments, and sometimes it is far too easy to put the blame on another party for whatever fails to transpire. If, however, we consider the four C's approach to this situation:

- Communication: Exchanging ideas and information.
- Cooperation: Understanding the goals of all stakeholders to achieve the desired results while minimizing downtime.
- Collaboration: Working together collectively on a plan that could not have been designed by one party.
- Coordination: The ability of management to lead the team in completing the works (Macfadden, 2018).

then we can achieve the desired results. The success of the in situ diameter change in the tunnel is a result of this “four C's” approach between all parties involved with the project. It is obvious that the ability of the TBM manufacturer's engineering and management team and the contractors project team to communicate and understand the requirements of what had to be done resulted in the successful diameter change.

Moreover, it was the ability of the personnel carrying out the work to communicate on a daily basis to adapt to the problems they faced and come up with solutions as situations arose that led to the smooth transition from one diameter to another.

This was a unique time- and cost-effective solution to a not-so-common situation. A diameter change in mid-tunnel is a rare event. The success of this in-tunnel diameter change shows that with careful planning and cooperation there is an opportunity to use this method, albeit adapted to the particularities of any project, that would require a similar mid-bore diameter change in the future. ■

References

- Macfadden, M. (2018, Jan. 3). The four Cs: Communication, Coordination, Cooperation, and collaboration. Convergence Labs. Retrieved October 27, 2021 from <https://convergelabs.com/blog/2018/01/the-four-cscommunication-coordination-cooperation-and-collaboration/>.
- Rowland, J. (2019, Oct. 24). One TBM for two-diameter Mill Creek Alignment. TunnelTalk. Retrieved from <https://tunneltalk.com/USA-24Oct-19-Robbins-TBM-to-bore-two-diameter-Mill-Creek-drainage-project.php>.

UCA hosts Cutting Edge and George A. Fox Conferences

The United Nations estimated the world's population would hit 8 billion people on Nov. 15, 2022 and that it would climb to 10.4 billion by the end of the century. According to the World Bank, 56 percent of the world's population now lives in cities or urban areas and that trend is expected to continue with urban populations more than doubling its current size by 2050 to a point at which nearly 70 percent of the world's population will live in urban areas.

This growth of urban areas will undoubtedly lead to challenges of accelerated demand for affordable housing, employment, basic services and a viable infrastructure that includes transportation systems, water, sewage and other utilities.

According to the World Bank the expansion of urban land consumption outpaces population growth by as much as 50 percent and 1.2 million km² of new urban built-up area will be added by 2030. This will add immense pressure on land and natural resources around the world. Cities already represent two-thirds of global energy consumption and produce more than 70 percent of greenhouse gas emissions.

Where cities can no longer expand out or up they will increasingly look to grow below ground. Tunnels and underground infrastructure have always provided a solution to many urban growth challenges, and as the world confronts climate change and a need to decarbonize, tunnels will continue to play an essential role in the global efforts to meet the climate goals set by the Paris Accord. Mass-transit tunnels like the proposed West Seattle Project in Seattle, WA or the Sepulveda Pass tunnel in Sacramento, CA could help remove thousands of vehicles from daily commutes and the emissions that come from them. Combined sewage overflow tunnels, such as the Thames Tideway Tunnel in London, England will help clean the Thames River and the city itself. And increased underground infrastructure can help make way for useable space above such as a community park over Interstate 70 in Denver, CO.

However, just because the end result of tunnels provides many solutions to the challenges presented by urban growth, the tunneling industry has found that is

In November 2022, nearly 300 people gathered in Long Beach, CA for the 2022 Cutting Edge Conference hosted by UCA and Tunneling Journal.



does not get a pass for the means in which the tunnels are constructed.

On the same day the global population hit the 8 billion mark, nearly 300 of those people gathered in Long Beach, CA for the 10th Annual Cutting Edge Conference presented by UCA and *Tunneling Journal*. The issues of advances in tunneling technology and specifically, the industry's role regarding sustainability and carbon neutrality were top-of-mind for the two-day conference that has earned a reputation for its high-quality programming.

Andy Alder, Tideway project director, Jacobs opened the conference with a keynote address that focused on the social value delivered by the Thames Tideway Tunnel Project, a 25 km (16 mile) tunnel in London, England that will intercept, store and ultimately transfer sewage waste away from the River Thames. The project itself is one of the most impressive tunneling projects in the world as it incorporated six tunnel boring machines (TBM) to complete the 7.2 m (24 ft) diameter tunnel, and while Alder could speak at length about the engineering feats associated with the tunnel, he instead focused on the other impacts of the project.

London's combined sewer system has been overwhelmed by the population growth of the city. The original system was built when there were about 2 million people in the city compared to the current population of nearly 10 million. Rains can often overwhelm the system's capacity, leading to about 40 million tons of sewage overflows into the river. From an environmental stance, this overflow destroys wildlife and is a massive public health hazard, Alder said.

The environmental and public health issues were

William Gleason, Editor

Nine scholarship winners (not in order) Maksymilian Jasiak, Hassan Al Kaaby Al Zoaby, Karen E. Mena Arango, Pa Ousman Njie, Valli Eugenio, Jack Lawrence, Milad Ghahramanieisalou, Wendi Zhao, Charbel Beaino and Mustafa Suner were given scholarships by the Cutting Edge Conference committee.

drivers for many of the decisions made on the project.

“Our mission is to prevent sewage from getting to the River Thames, and by extension we are making the river something that adds value to the city,” Alder said. “We wanted to embrace that vision and we set out to create a legacy and a commitment to the environment, and the health, safety and wellness of the people in London.”

Alder noted that the project committed to reducing carbon emissions through the use of electric-powered cranes over diesel power and to use the river itself for the transportation of construction materials. Using barges on the river had the added health and safety benefit of reducing the need for transportation on roads by about 50,000 loads.

Alder also spoke about the project’s commitment to the community to employ a large local workforce including people who have had previous legal or financial troubles. The project also set high diversity and inclusion standards. Some of the commitments included personal protective equipment (PPE) for males and females as well as PPE that is inclusive for religious traditions.

The Cutting Edge Conference was established in 2012 and has grown in the past decade thanks in part to a reputation for presentations about cutting-edge technology and practices in the industry. This year the program included many high-level technical talks as well as an important discussion about mental health.

Robert Labbe from American Global gave a very personal presentation about the need to look out for each other. The construction industry is a male-dominated industry with high stress, long hours, many military veterans and unfortunately, an unacceptably high suicide rate. While the issue of mental health has moved from the shadows in many parts of society, it can be difficult to talk about in some sectors such as the construction industry. Labbe stressed the importance of checking in and keeping an eye on friends and coworkers in the industry.

Carbon emissions

One of the central themes during Cutting Edge 2022 was how can the industry improve its environmental, social and governance (ESG) status. Yes, tunnels are often part of the solution for a greener environment, but the construction of tunnels and of tunnel boring machines (TBMs) and other equipment often requires a large carbon output.

During the conference there were presentations about



innovations in tunneling and the challenges that exist in getting to lower carbon through alternative means and methods. There was also significant time spent focused on incorporating sustainability into the planning of projects including a panel discussion focused on sustainability and carbon neutrality.

“In the UK we are seeing the public demand change that our projects are more sustainable,” said Adler. “We need to get the public’s support and convince the public that we are driving toward net zero. If we cannot get public support we won’t get political support either.”

During a panel discussion, Fernando Vera, Wolfgang Aldrian, Alder and Chris Nelsen spoke about the challenges in making the tunneling industry more sustainable. Some of the issues facing the industry include getting support from clients and finding alignment with local and national governments.

The panel agreed that ultimately there has to be a framework that is flexible. Sustainability should be seen with the same level of importance as health and safety programs, and the players in the industry should recognize that it is a collaborative effort that includes the right funding and the right policies to make everything work. This will require innovation, and the risk should be shared between owners and contractors.

From an engineering perspective, Katherine Westerlund gave an impassioned presentation on the need for the industry to confront the challenges presented by climate change head on.

The decarbonization of equipment and construction materials is another issue that was discussed during the panel discussion and beyond. Werner Burger of Herrenknecht spoke about the rising trend of refurbishing equipment such as TBMs to greatly reduce the amount of carbon emissions needed to construct the machines.

The refurbishment of TBMs is a complex process that must be considered early in the planning phase of any project. There is a finite number of TBMs in the world and the diameter of the proposed tunnel must work with the diameter of the machine. There is also the challenge of incorporating state-of-the-art technology into a machine that was constructed for a project five to 20 years earlier.

Decarbonized construction material was also discussed during the conference. The fundamentals of tunneling remain largely unchanged, but new and more efficient materials offer potential improvements for the industry.

More than 480 attend 2023 George A. Fox Conference in New York City

On the same day that President Joe Biden was in New York City to announce \$292 million in funding for part of the Gateway Rail Project, many professionals in the tunneling industry were gathered just a few miles away for the George A. Fox Conference at the New York Hilton Midtown.

The president's visit on Jan. 31 did create a scheduling conflict for Kris Kolluri, chief executive officer of Gateway Development Commission who had been scheduled to present at the Fox Conference on the project but was pulled away to speak with President Biden about the funding that will be used to finish the Hudson Yards tunnel box.

On Jan. 31, President Joe Biden announced \$292 million in funding for the Hudson River tunnel project. (Photo credit: Gateway Development Commission.)



Eric Daleo, chief program officer and Megan Strickland, deputy chief program officer both of the Gateway Development Commission presented in place of Kolluri and gave updates on what the commission is planning.

In light of the expected announcement of funding, the commission, which is composed of representatives from New York, New Jersey and Amtrak, is building the legal and financial capacity to manage the project. Strickland said there is good momentum for the project and the commission will work to keep that going.

The *Associated Press* reported that the \$292 million mega grant announced on Jan. 31 is part of \$1.2 billion in mega grants being awarded under the 2021 Bipartisan Infrastructure Law.

The grant will be used to finish the Hudson Yards tunnel box concrete casing, a project that was started in the summer of 2013 to preserve the route of the Gateway Tunnel from Penn Station to the Hudson River as foundations were built for the Hudson Yards project.

"We are looking at this as an early action construction project that will move ahead this year," Daleo said. "It is a critical project that preserves a right of way and allows for development above ground and leads the other packages."

The Hudson Yards Concrete Casing – Section 3 is one of nine nationally significant projects selected for this first year of the program out of 100 applications, U.S. Transportation Secretary Pete Buttigieg said in a statement. This grant will be funded over the course of four years from fiscal years 2022 to 2025.

Another early construction project is at the Tonnelle Avenue Bridge. It was the first project that was undertaken 10 years earlier when the project was still called the Arch Project before it was canceled. Daleo said the Gateway Development Commission planned to issue a request for proposal for construction management and invitation for bid for services within a month for the Tonnelle Avenue Bridge work.

The Gateway project will be a renovation of the 1910 tunnel already carrying about 200,000 weekday passengers beneath the Hudson River between New Jersey and Manhattan, a long-delayed upgrade after decades in which the government underfunded infrastructure.

Arnold Dix, president of the International Tunnelling and Underground Space Association and barrister, scientist and professor of engineering of counsel, White & Case gave the keynote presentation at the Fox Conference in which he emphasized the need for the industry to make a case to President Biden and other world leaders that tunneling and underground construction provides sustainable solutions for society.

"It's no accident that President Biden is here meeting about the projects that you are working on," said Dix. "The sustainability agenda is listed as part of the United States' national security agenda. That tells you that the money and resources that you need to deliver your projects are nearby. That challenge is to make sure that your projects

Arnold Dix, president of the International Tunneling and Underground Space Association and barrister, scientist and professor of engineering of counsel, White & Case gave the keynote presentation at the Fox Conference.

address the national security agenda in the delivery of health and wealth and well-being for your communities.”

The grant announced by Biden would also be used to help complete the concrete casing for an additional rail tunnel beneath the river, preserving a right of way for the eventual tunnel. In total, the project is expected to cost \$16 billion and help ease a bottleneck for New Jersey commuters and Amtrak passengers going through New York City.

Other projects to receive mega grants include the Brent Spence Bridge, which connects Kentucky and Ohio; the Calcasieu River Bridge replacement in Louisiana; a commuter rail in Illinois; the Alligator River Bridge in North Carolina; a transit and highway plan in California; and roadways in Oklahoma, Pennsylvania and Mississippi.

Along with the announcement from the Biden administration, the Fox Conference included a number of talks about the current state of the industry and the projects that are in the works or are expected to begin soon. Good news for the industry and attendees, but also challenging news. Like many industries, the tunneling and underground construction industry is challenged with significant workforce issues. The hours can be long, and the industry can be demanding with professionals asked to relocate around the nation and even the world. And for the most part, the work of a tunneling professional goes largely unseen. The industry is also one on which many of its top-tier professionals are nearing retirement, thus a knowledge gap is looming.

One of the afternoon sessions was a continuation of a panel discussion that began at the previous Fox Conference and focused on these workforce challenges.

More than 480 people attended the George A. Fox Conference at the New York Hilton Midtown on Jan. 31.



Mike Rispin, vice president of tunneling, Strata Worldwide and UCA Chair moderated a panel discussion that included Elisa Comis, managing director, Pini Group USA Inc. and member of UCA Women in Tunneling;

Vojtech Gall, senior tunnel engineer, Gall Zeidler Consultants and member of UCA Young Members; Everett Litton, assistant vice president, WSP - UCA Student Outreach / Down for That and Mike Mooney, Grewcock Chair, professor of underground construction and tunneling, Colorado School of Mines and coordinator of UCA's Teach the Professors program.

The panel addressed three overall questions:

1. What do we need to do differently to make a career in the underground construction industry more attractive to young professionals?
2. What do we need to do to improve retention of the young people currently in the industry?
3. What should we be doing to market the industry?

While the answers from the panel covered a breadth of issues it was generally agreed upon that the industry needs to engage with students at the high school or even grade school level to create awareness of the good things it has to offer. And the inherent sustainability of tunnels for the improvement of society is an important aspect to be promoted to young people who want to have a career that has a positive impact on society.

At the conclusion of the panel discussion the audience was asked to carry the positive messages of the tunneling and underground construction industry forward to their local schools. ■



From the American Underground Construction Association to the current-day UCA

The Underground Construction Association (UCA), formerly known as the American Underground Association (AUA) was established in 1975 when representatives from a number of construction organizations realized the need for an association focused on tunneling and underground construction.

In the ensuing decades the AUA established itself as the leading association for professionals in tunneling and underground construction.

In the 1990s, the AUA took over U.S. representation to the International Tunnelling Association and initiated the North American Tunneling (NAT) Conference. In 2000, the AUA established the George A. Fox Conference.

In 2006, the AUA merged into the Society for Mining, Metallurgy & Exploration (SME) to become the Underground Construction Association (UCA), a Division of SME. By doing so the UCA gained the benefits of SME's professional association management team and its members gained full access to SME benefits.

The UCA continues to manage the NAT conference (even years), the Rapid Excavation & Tunneling Conference (RETC) (odd years) and the George A. Fox Conference. In 2012, the annual Cutting Edge Conference in conjunction with *Tunneling Journal*, AUA's quarterly publication, *AUA News*, was discontinued and in September 2006, *Tunneling and Un-*

derground Construction (T&UC) was launched as a quarterly publication to cover the tunneling and underground construction industry. The Tunnel Demand Forecast moved from the AUA publication and continues to this day in *T&UC*.

In 2023, the UCA is a growing community of tunneling and underground construction experts with more than 1,700 members. The UCA supports a variety of conferences, committees and workforce development efforts to bring its mission alive. While focused on the future, it is also important to reflect on how the UCA began.

History

The AUA was founded to promote the development and use of underground facilities. Charles Fairhurst, who was head of the Civil and Mineral Engineering Department at the University of Minnesota, was its first president. Members included U.S. and international professionals who were interested in the planning, design and construction of underground facilities.

Underground associations links

Beginning in 1986, the AUA initiated links with other underground associations and committees including the ITA, the Underground Construction Research Council, the U.S. National Committee on Tunneling Technology (USNC/TT), the

Institute of Shaft Drilling Technology (ISDT), the North American Society for Trenchless Technology (NASTT), the Association of Engineering Geologists (AEG) and the American Institute of Architects (AIA).

AUA – Representation

Since its founding, the AUA has had a significant international membership — at one point the association had members from 25 countries outside of the United States. Since 1987, representatives of AUA have attended ITA conferences and some have been elected to the ITA Executive Council including Jack Lemley, Dan Eisenstein, Dick Robbins, Harvey Parker, Amanda Elioff, Randy Essex, Jamal Rostami and Sanja Zlatanic. Lemley, Eisenstein and Parker were elected as ITA presidents, and Robbins, Elioff, Essex and Rostami were elected as ITA vice presidents.

Many AUA members have led ITA working groups. Because of this involvement, the AUA was confirmed as the U.S. representative to ITA when the USNC/TT was disbanded in 1993-94. In 1996 and again in 2016, AUA/UCA hosted two ITA conferences in the United States. The AUA was also a sustaining member of the Associated Research Centers for Urban Underground Space (ACUUS), representing planning of underground space and facilities around the world. ■

McMillen Jacobs rebranded as Delve Underground

McMillen Jacobs Associates, specializing in delivering underground infrastructure throughout North America and Australasia, is pleased to announce it has rebranded as Delve Underground.

"Delve Underground's mission is to solve our clients' infrastructure challenges with our collective expertise and legacy of underground excellence," said Victor Romero, president of Delve Underground.

"Our new name reflects our company culture of working collaboratively and delving deep to inspire bold and responsive solutions."

Founded in 1954 as Jacobs Associates, Delve Underground is an employee-owned heavy civil engineering firm serving the water, wastewater and transportation markets.

"With 21 offices and 350 team members, we offer comprehensive design, design-build, construction

management, and dispute resolution capabilities," the company said in a press release.

"The rebrand was a thoughtful and well-planned effort that involved our clients and team members from across our offices," said Gregg Davidson, chief operating officer of Delve Underground. "Our new brand is modern and creative, yet retains the spirit of our underground roots." ■

International Tunneling Awards announced; Two U.S. projects win prestigious awards

The International Tunneling and Underground Space Association (ITA) announced the winners of its 2022 awards, and American projects and engineers were represented in the international competition that is in its eighth year.

Organized by the ITA, the awards showcase the most ambitious underground projects all over the world as well as the latest innovations, techniques and methods in tunneling.

Major Project of the Year

The Purple Line Expansion project in Los Angeles, CA was named the Major Project of the Year winner. This award is for projects with budgets of more than €500 million (\$530 million). The Skanska-Traylor-Shea joint venture (STS) is constructing the \$1.9 billion design-build of the Purple Line Extension, Section 1, in Los Angeles, CA. This is the first of three projects to extend the Purple Line from Wilshire/Western Station to Santa Monica, a tunnel project that has been in the works for more than 60 years.

This portion of the project will add 6.3 km (3.92 miles) to the Purple Line, beginning at the Wilshire/Western Station. The twin tunnel alignment travels beneath Wilshire Boulevard, and underground stations are under construction at Wilshire/La Brea, Wilshire/Fairfax, and Wilshire/La Cienega.

The tunnels, mined by two Herrenknecht tunnel boring machines (TBMs), are 10,287 m (33,750 linear ft) long with an inner diameter of 5.7 m (18.8 ft).

Technical Innovation of the Year

The Technical Innovation of the Year was awarded for the “unprecedented in-tunnel diameter conversion of the largest hard rock TBM in the United States.”

The largest hard rock TBM ever to bore in the United States, an 11.6 m (38 ft) diameter main-beam TBM, recently underwent a planned in-tunnel diameter change to a more compact 9.9 m (32 ft). The first-of-its-kind con-

version process for the main-beam TBM was undertaken 2.8 km (1.7 miles) into the bore and was not done inside a shaft or pre-excavated portal (see feature on page 13).

Young Tunneller of the Year

Erica Frederickson was named the Young Tunneller of the Year.

“Just two weeks after graduating from university in 2011, I started my career in the tunneling industry. I got my first taste of tunnels as a field engineer with Traylor Bros. Inc. on the NYC MTACC LIRR East Side Access Queens Bored Tunnels and Structures project,” Fredrickson wrote. “Looking back, I had no real idea of what to expect, other than I thought underground construction seemed “cool.” I did not expect to continue working for the same company and industry for 11 years, but there is something special about the tunneling industry that hooked me.

“Since that first job, I have worked on three more tunnel projects in three different cities across North America: the DC Water Blue Plains Tunnel in Washington, DC; the LACMTA West-

side Purple Line Extension Section 1 in Los Angeles, CA; and the Second Narrows Water Supply Tunnel in Vancouver, BC. Each project has had its share of challenges, triumphs, stressed-out moments and opportunities for growth. But most of all, I remember each project for the friendships formed with my incredible colleagues who call tunneling their career, and for the reward of providing essential infrastructure that will improve the lives of millions for many years to come.”

2023 ITA Awards

- **Tunneling project of the year** (€50 million-500 million) – World’s first spiral excavation using H&V shield tunneling method (Japan).
- **Project of the year** (Up to €50 million including renovation) – Guanyinyan tunnel, an urban tunnel project of the unequal span four-arch-tunnel with two-ways and 10 lanes (China).
- **Beyond engineering** – Multipipe jacking method for the construction of city core metro station in soft soil. ■

Mike Rispin (L), chair UCA, and Arnon Dix (R) president, International Tunneling Association, congratulate Henry Russell, PE, PG, on receiving the ITA Distinguished Service Award for being the animateur (Chair) of the ITA Working Group 6 Repair and Maintenance of Tunnels for 20 years. During Russell’s leadership, the working group developed two significant documents: Study for the Repair of Tunnel Liners, 2001 and Guidelines for Structural Fire Protection for Road Tunnels, 2013, which has become the basis for current fire protection for road tunnels in the United States.



TUNNEL NAME	OWNER	LOCATION	STATE	BID YEAR	TUNNEL USE	LENGTH (FEET)	WIDTH (FEET)	STATUS
Potomac River CSO Tunnel	DC Water and Sewer Authority	Washington	DC	2023	CSO	24,000	18	Proposal bid 4/23/2023
Minneapolis Central City Parallel Tunnel	City of Minneapolis	Minneapolis	MN	2023	CSO	4,200	10-19	Final planning
I-70 Floyd Hill Highway Tunnel	Colorado Dept. of Transportation	Denver	CO	2023	Highway	15,840	60 x 25	Under design
Folsom Area Storm Water Improvement	SFPUC	San Francisco	CA	2023	CSO	4,000	12	Under design
Downtown Extension (DTX)	TJPA	San Francisco	CA	TBD	Transit	TBD	TBD	Under design
CA High Speed Rail (Northern Section)	CA High Speed Rail Authority	Fresno	CA	2023	Transit	TBD	TBD	Design 3Q 2023
CA High Speed Rail (Southern Section)	CA High Speed Rail Authority	Bakersfield	CA	2023	Transit	TBD	TBD	Design 3Q 2023
West Santa Ana Line	LACMTA	Los Angeles	CA	2023	Transit	TBD	20	RFQ pending
Ontario Airport Tunnel	San Bernardino Co. Trans. Authority	San Bernardino	CA	2023	Transit	22,000	24	Under design
Gateway Tunnel Project	Amtrak	Newark/New York	NJ/NY	2023/2024	Transit	14,600	28	PDP Procurement ongoing
2nd Ave. Phase 2	NYS-MTA	New York	NY	2023	Subway	16,000	20	Fed approval process ongoing
2nd Ave Phase 3-4	NYS-MTA	New York	NY	2024-2029	Transit	89,600	20	Under study
Amtrak B&P Tunnel	Amtrak	Baltimore	MD	2023	Rail	40,000	32	PDP Procurement ongoing
Alum Creek Relief Tunnel Phase 1 Phase 2	City of Columbus	Columbus	OH	2023 2024	Sewer	30,000 21,000	18 14	Under design Under design
Ontario Line North Extension	Metro Linx	Toronto	ON	2023	Subway	29,500	20	RFP in 2023
West Vaughn Sewage Servicing Project	York Region	Toronto	ON	2023	Sewer	36,000	10	RFQ shortlist completed
Yonge North Subway Extension	Metro Linx	Toronto	ON	2023	Transit	40,000	20	RFQ Pending
Blue Line Extension	Societe de transport de Montreal	Montreal	QC	2023	Transit	19,000	33	Under design
REM-S Project	Societe de transport de Montreal	Montreal	QC	2023	Transit	23,000	33	Under design
Southerly Storage Tunnel	NEORS	Cleveland	OH	2023	CSO	18,000	23	Under design
DELORCA Wastewater Tunnel	DELCORA	Chester	PA	2023	CSO	45,500	13	Under design
Enbridge Line 5 Tunnel	Enbridge	Traverse City	MI	2023	Oil	23,760	12	Bid Submitted
Mill Creek Trunk Improvements	City of Nashville	Nashville	TN	2023	CSO	13,800	10	Under design
Green Line LRT	City of Calgary	Calgary	AB	2023	Transit	9,000	40	RFP submitted
Nose Hill Project	City of Calgary	Calgary	AB	2023	CSO	10,800	10	Under design
Kensico-Eastview Connection Tunnel	NYC-DEP	New York	NY	2024	Water	11,000	27	Under design

TUNNEL NAME	OWNER	LOCATION	STATE	BID YEAR	TUNNEL USE	LENGTH (FEET)	WIDTH (FEET)	STATUS
Silver Line Extension	Boston Transit Authority	Boston	MA	2023	Transit	8,400	22	Under design
Yonge North Subway Extension	Metro Linx	Toronto	ON	2023	Transit	40,000	20	RFQ Pending
Stanley Park Water Supply Tunnel	City of Vancouver	Vancouver	BC	2023	Water	5,000	15	RFQ Q4 2023
ALCOSAN CSO Ohio River Allegheny River Monongahela River	Allegheny Co. Sanitary Authority	Pittsburgh	PA	2025 2028 2030	CSO CSO CSO	20,000 28,000 28,000	18 18 18	Under design Under design Under design
Germantown Winghocking Relief	City of Philadelphia Water	Philadelphia	PA	2025	CSO	28,000	20	Under design
Project Connect Subway Program	City of Austin	Austin	TX	2025	Transit	8,500	20	Design delayed
West Seattle to Ballard Extension	Sound Transit	Seattle	WA	2025	Transit	10,500	20	Under design
Northside Interceptor Tunnel	City of Akron	Akron	OH	2025	CSO	6,850	24	Under design
Taylor Massey Tunnel	City of Toronto	Toronto	ON	2025	CSO	20,000	15	Under study
Quebec City - Levis Tunnel	Quebec Trans. Ministry	Quebec	QC	2025	Transit	27,230	60	Under study
Del Mar Bluffs Tunnel	SANDAG	San Diego	CA	2025	Rail	TBD	TBD	Under study
Fraser River Tunnel	BC Ministry of Transportation	Vancouver	BC	2025	Highway	3,000	TBD	RFP expected
Queensway Tunnel	Region of Peel	Toronto	ON	2025	Sewer	18,000	9	RFP Ongoing
Stormwater Control Program	Harris Co. Flood Control District	Houston	TX	2026	CSO	52,800	25-40	Under study
LA Metro Sepulveda Pass Corridor	Los Angeles MTA	Los Angeles	CA	2026	Transit	55,000	TBD	Under design
D2 Subway - 2nd Light Rail Alignment	Dallas Area Rapid Transit	Dallas	TX	2026	Transit	7,230	22	Delayed
Flushing Bay CSO Tunnel	NYC-DEP	New York	NY	2026	CSO	16,500	22	Under study
Cross Harbor Freight Tunnel	PANYNJ	New York	NY	TBD	Rail	25,000	30	Under study
Superconducting Maglev Project - Northeast Corridor	TNEM/BWRR	Washington	DC	TBD	Rail	146,500	43	Under design
Big Creek Storage Tunnel	NEORS	Cleveland	OH	2026	CSO	22,450	20	Under design
Metropolitan Tunnel Program - Northern Tunnel Southern Tunnel	MWRA	Boston	MA	2027 2028	Water Water	23,760 55,000	10 10	Under design Under design
Horizon Lateral Tunnel	Southern Nevada Water Authority	Las Vegas	NV	2027	Water	42,000	9	Delayed
Inner Harbour West Tunnel	City of Toronto	Toronto	ON	2027	CSO	18,400	20	Under design

To have your major tunnel project added to the Tunnel Demand Forecast, or to update information on a listed project, please contact Sanja Zlatanic at szlatanic@hntb.com.



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The Herrenknecht Group achieved a total output of 1,185 million euros in 2021. The independent family-run business employs around 5,000 people worldwide, including around 200 trainees. With around 70 subsidiaries and associated companies working in related fields in Germany and abroad, Herrenknecht is able to provide a comprehensive range of services close to the project site and the customer, quickly and in a targeted way. Under the umbrella of the Herrenknecht Group, a team of innovative specialists offers integrated tunnelling solutions with project-specific equipment and service packages upon request: separation plants, belt conveyor systems, navigation systems, rolling stock systems as well as segment moulds and even turnkey segment production plants.

As a reliable project partner, Herrenknecht supports its customers with an extensive range of services from the beginning of the project to breakthrough. From the initial project idea through manufacturing, transport, assembly, tunnelling support and spare parts service to disassembly, Herrenknecht accompanies the process at the customer's side. Even personnel solutions for the temporary supplementing of jobsite crews are provided if required. With competent service specialists and more than 45 years of experience in the tunnelling industry, the company regularly supports around 300 jobsites worldwide and offers customized service packages tailored to individual project requirements.

Road, metro, and railway tunnels for efficient traffic network. By the middle of this century, the world's population is expected to reach nine billion, and two thirds of these people will live in large conurbations. To keep people and goods on the move, the way ahead for new efficient infrastructures is leading underground. With state-of-the-art technologies, efficient infrastructures are created exactly where they are needed, even in cramped and complex jobsite conditions. Herrenknecht technology pushes the boundaries of feasibility and creates new tunnelling standards worldwide. Herrenknecht technology extends existing transport networks and creates new connections in urban and rural areas – under mountains or deep beneath water.

Innovative solutions for underground supply and disposal systems. As the world's population grows the need for underground supply tunnels is also increasing; in emerging and developing countries as well as in modern metropolises. That is why more than 850 Herrenknecht Utility Tunnelling Machines are in operation around the world constructing or laying water and wastewater systems, gas and oil pipelines, as well as conduits for electricity and telecommunications. Here, trenchless tunnelling technology offers a range of advantages compared to conventional construction procedures: transport, business and the environment remain mostly undisturbed when Micromachines, HDD rigs or shaft sinking equipment are being used. Innovations such as Direct Pipe® set new standards in the semi-trenchless installation. The new technology E-Power Pipe® allows the secure and quick installation of underground cable protection pipes with smaller diameters and long advance lengths. Innovative HDD tools simplify pipeline construction operations at key sections. The Herrenknecht product portfolio is completed by a broad range of equipment for the areas of mining (construction of underground infrastructures around raw material deposits) and exploration (oil, gas and geothermal energy).

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EarthGrid is approved as a utility in 26 states, representing >73% of the US population, allowing EarthGrid to obtain access to public rights of way for its tunnels and trenches.

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Antraquip Corporation continues to solidify its position as a leading designer, manufacturer and supplier of roadheaders, hydraulic rock cutting attachments, shaft sinkers, specialty tracked machines with a variety of boom options as well as ground support solutions for NATM tunnels.

Within Antraquip's rock cutting attachment product line, Antraquip has introduced diamond and carbide saw attachments for excavators ranging from 1 to 60 tons. Additionally, Antraquip has designed and manufactures the world's most powerful rock cutting attachment with 400 kW+ cutting power for excavators in the 80+ ton weight class. By continuing to invest heavily into research and development Antraquip strives to be able to cut hard rock which has previously not been possible with mechanized excavation methods.

As to roadheaders, Antraquip offers not only standard roadheaders in the 12 – 85 t on class but is proud to offer project oriented engineering solutions whenever requested and necessary. Some of the recent projects have included AQM roadheaders equipped with customized drilling attachments, fully automated remote control systems and automated guidance systems.

Within its ground control program, Antraquip specializes in any support product needed for NATM as well as drill and blast tunnels like lattice girders, steel ribs, specialized rock bolts, spiles, wire mesh and arch canopy systems (barrel vault system or arch pipe system).

In addition to offering project consultations, innovative cutting and support solutions, Antraquip recognizes the importance of after sales service. This commitment to offering the best service and technical support is carried out by highly proficient and experienced service engineers and technicians, all reinforced with large spare part inventories at hand. Innovation, reliability and experience offered by Antraquip makes them a reliable partner for any tunneling project.

Antraquip's main goal is: SAFETY, SAFETY and again SAFETY! Antraquip continues to strive to offer innovative products to make any job safer, faster and increase the bottom line for any contractor and owner.

Antraquip is well represented all over the world, but takes pride in paying detailed attention to any local tunneling challenge small or large.

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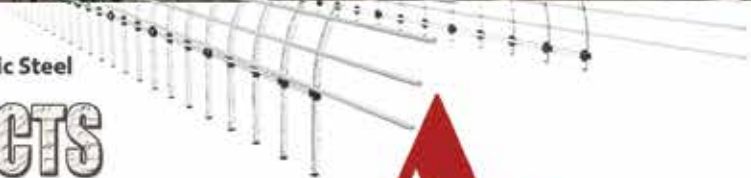
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TERRATEC products are well-known in the industry as Robust, Durable and Safe, basic principles that must prevail in the design of any equipment made to work in the extreme conditions encountered underground. As a provider of Total Tunnelling Solutions, TERRATEC's scope of work extends to custom engineering, as well as the operation and maintenance of tunnel boring equipment and the supply of ancillary equipment.

TERRATEC's capacity to provide a wide range of services means that it is not only an equipment supplier but a qualified and experienced partner in the execution of tunnelling works.

As a result, it is becoming more and more common for TERRATEC to supply a Total Tunnelling Solution package consisting of the TBM/s, other main equipment in the tunnel (Trains, Conveyors, Segment Moulds and Ventilation), spares and consumables for the equipment and a team of TERRATEC field personnel who can assist in the operation and maintenance of the supplied equipment throughout the duration of the project.

TERRATEC offers full range of equipment from pipe jacking machine to open TBM, soft ground to very hard rock machine. TERRATEC's continuing success on global projects is a result of tailor-made robust TBM design, prompt onsite assistance, readily available stock of TBM spares and highly-skilled specialised TBM support throughout tunnelling operations.

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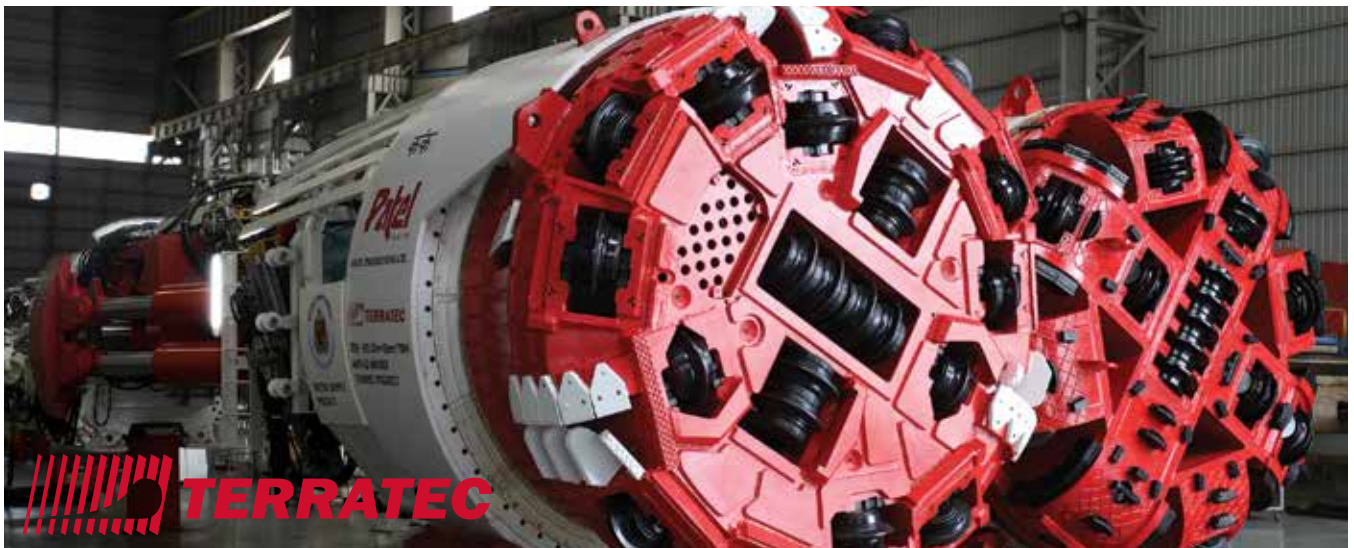
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Award-Winning Projects

UCA Project of the Year Award (2022), projects between \$50 to \$500M, Bergen Point Southwest Outfall Replacement

MEED Project Award (2020), International Project of the Year, Ismailia Tunnels under Suez Canal

ACEC Engineering Excellence Award (2018), New York Harbor Water Siphon

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JENNMAR continues to grow, but our focus will always be on the customer. We feel it is essential to develop a close working relationship with every customer so we can understand their unique challenges and ensure superior customer service. Our commitment to the customer is guided by three words: SAFETY, SERVICE, and INNOVATION. It's these words that form the foundation of our business. It's who we are.

JENNMAR Civil, a brand of JENNMAR has been working on some exciting projects over the past year. See photos and description below:

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JENNMAR Civil and Turnstone Industrial Solutions are excited to be a part of the design-build Atlanta Plane Train Tunnel West Extension Project at Hartsfield-Jackson Atlanta International Airport, where JENNMAR Civil supplied lattice girders, bolts, and shaft ground support products to reinforce the terminal and sky train above. Turnstone Industrial Solutions LLC. supplied ventilation and tunnel liner.



The project includes extending the current automated people mover system and renovating the baggage claim facility increasing its passenger capacity from 10,000 an hour to 12,000 an hour. JENNMAR Civil and Turnstone Industrial Solutions LLC. are proud to be on-site for this The City of Atlanta project.

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JENNMAR Civil offers a wide range of products used in supporting, building and rebuilding our infrastructure from above and below ground. Our strength lies in our ability to offer our customers solutions in every phase of their projects. We manufacture arch systems, girders, liner plates and Impact Resistant Laggings® and much more for your projects. Whether mining, rehabbing or re-supporting transportation, water, wastewater or infrastructure tunnels, Jennmar Civil is backed by experienced engineers and technicians who are with you every step of the way, from initial consultation to qualified instruction and on-going technical support to make your project a success!

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For more information on our portfolio of diverse and complementary brands visit us at www.jennmar.com.

MAPEI Corporation

MAPEI's Underground Technology Team (UTT) provides the construction market with a range of products dedicated to underground construction work. MAPEI's UTT group and the products it represents were created to meet the expectations of these challenging environments. From the project specification to the admixtures for shotcrete and concrete to the final protective coatings, MAPEI's UTT group and technology are there "for the whole job," said Cristina Onate, PhD, UTT Business Development Manager — Tunneling.

The UTT group is a successful division of MAPEI Group, which has provided proven construction system solutions for more than 80 years. Established in 1937, MAPEI Group is a global corporation, based in Milan, Italy, and with 91 subsidiaries that include 84 plants in 35 nations. MAPEI is the

world-leading manufacturer of mortars, grouts and adhesives, as well as complementary products for installing floor and wall coverings. MAPEI manufactures chemical products for building, including waterproofing products, admixtures for concrete and repair products, and decorative and protective exterior coatings — as well as the UTT product line.

"The UTT group started in earnest in the U.S. in 2015," stated James Pinkley, Country Manager UTT — North America. "But the business has grown substantially since then." In the underground industry, speed is essential — not only of the products themselves, but also of the evolution of technology. MAPEI reinvests a considerable percentage of its annual profits back into research and development to maintain a leading technological advantage. MAPEI's commitment to R&D ensures that the UTT line comprises the most innovative and technologically advanced products available. In addition to the latest in cutting-edge products, the UTT team is trained in their use, with decades of experience in the underground marketplace.

The UTT product line is divided into six categories: Mechanized Tunneling; Injections for Heavy Civil and Mining Applications; Waterproofing & Water Membranes; Shotcrete Products; Renovation, maintenance and repair; and Coatings for underground construction. No matter the division or the product line, MAPEI is known for quality products and for providing system solutions. As Pinkley stated, "The distinguishing point for UTT is our field support, and our applied technology in the field. Simply put, we don't just sell a product, but rather we go into the field and help our customers use our products — on their jobsite, with their conditions, personnel and equipment. MAPEI UTT services a project from the very beginning to the very end like no one else in the industry does," he said. "UTT also has the agility to adjust to the customers' needs when necessary per the demands of changing geological settings"

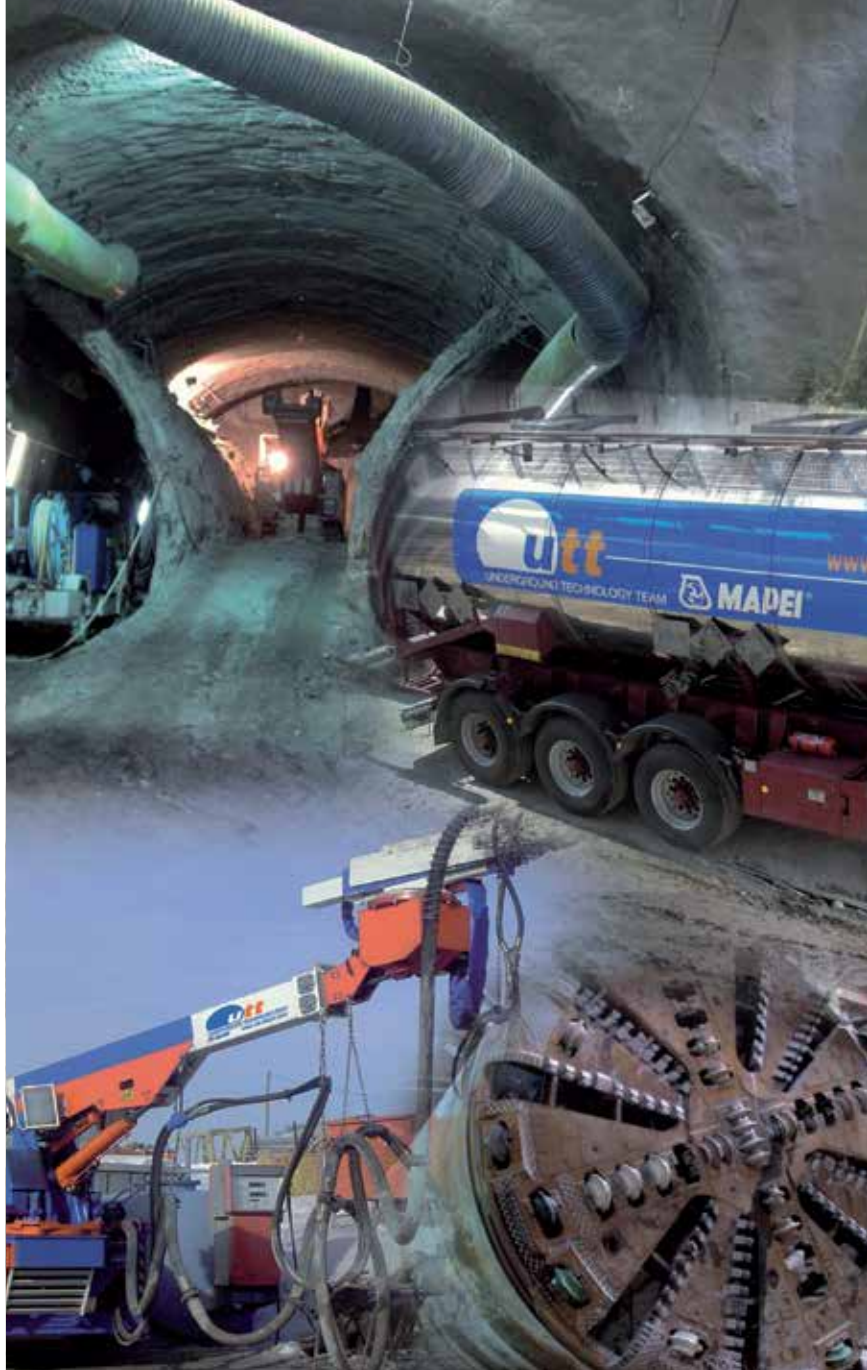
For more information, contact MAPEI's UTT group at www.utt.mapei.com.



MAPEI's UTT products were used to help a tunnel boring machine dig the Anacostia River Tunnel, which extends for 2.37 miles from Robert F. Kennedy Stadium in northeast Washington, D.C., to Poplar Point in southeast D.C.



Proven Technology for **Underground Construction**



Our commitment is the detail that makes the difference.

Reliable technology and expertise for underground construction

- Alkali-free set accelerators and admixtures for shotcrete
- Products for mechanized tunneling: foaming agents for soil conditioning, polymers, sealants and lubricants
- Products for grouting and consolidation
- Products for concrete repairing, protection and coating
- Products for waterproofing: synthetic waterproofing membranes and waterproofing accessories

Discover the world of MAPEI: Visit www.utt-mapei.com or email us at hq.utt@utt.mapei.com



Reliable Automatic Sprinkler Co., Inc.

Protecting the 'New M4' East Tunnel

About the Tunnel

The 'New M4' East (M4E) tunnel project is located in the inner west of Sydney, Australia. The M4E tunnel is a twin tube design of 3 lanes in both directions. Each tube is 5.5 km (3.4 miles) in length. Therefore, the project has approximately 11 km (6.8 miles) of tunnels in total. The tunnels are divided into 517 fire deluge zones along the entire length, including the covered entry & exit ramps. Each fire deluge zone is approximately 30 meters (98 ft) long. The tunnel is equipped with fibre optic detection that signals a central monitoring station. Each deluge zone is monitored by operators and manually activated.

When the specifications for the project were being developed, the design brief called for "an extended coverage nozzle that could effectively deliver 10 mm/min (0.25 gpm) density". At the time, no such product was commercially available. In response to this requirement, the Reliable® model TNL280 nozzle was developed.

About Deluge Systems

Deluge systems consist of water supply, a valve, a system of piping and nozzles that are open to atmosphere, and a means of detection and actuation. When the deluge valve is activated, water flows through all nozzles controlled by the valve. Unlike automatic sprinkler systems, where water flows only through individual sprinklers that have activated close to the heat source, deluge systems are designed to "surround and drown" an entire zone to prevent the spread of fire in hazardous environments.

About the TNL280 Nozzle

The Reliable TNL280 pendent nozzle has been specifically designed to provide an extended coverage nozzle suitable for use in vehicle tunnels. Key to the design of the nozzle is a very large K-factor (orifice size). The large nozzle coverage area typically results in lower installed costs by reducing the amount of material (pipe and hangers) and facilitates faster installation. By comparison, traditional tunnel nozzles — usually spaced at around 9 m² (97 ft²) — are much more material and labour intensive.

Project Quick Facts:

- Consulting Engineer: Norman Disney Young (NDY)
- Site Engineer: Jessica Keogh
- Number of Deluge Systems: 417
- Tunnel height: 5.3m (17.4 ft)

Learn More:

Reliable Automatic Sprinkler Co., Inc. is a manufacturer and distributor of fire protection equipment. Reliable manufactures the highest quality and most innovative fire sprinklers, valves, and special systems on the market. Reliable also distributes a full line of best-in-class system components. All Reliable products are backed with premier customer service. Reliable's corporate headquarters is located in Elmsford, NY with manufacturing headquarters in Liberty, SC. Regional sales and distribution centers are located throughout the US and around the world.

For more information on Reliable® products, systems, and innovation, visit our website at www.reliablesprinkler.com/tunnels



Disruption is not an option



Reliable® Tunnel Deluge Systems protect your most critical infrastructure assets

Reliable deluge systems are the perfect solution for the challenges of tunnel environments:

- The Model DDV Diaphragm Deluge Valve is simple to maintain and rated for pressures up to 400 psi (27.6 bar). Available with a remote resetting pressure regulating option, the Model DDV features a compact footprint and can be installed in any orientation.
- The industry-leading low-pressure/high density TNL280 nozzle features a corrosion-resistant Electroless Nickel PTFE (ENT) finish and anti-reflective black paint topcoat.



TNL280

Over 100 Years of Reliable Experience

Reliable Automatic Sprinkler Co., Inc. has been a trusted source for high-risk fire protection solutions since 1920. Our manufacturing headquarters are in Liberty, South Carolina, USA, while our Sales and Technical Services teams span the globe.

Reliable®

Manufacturer and Distributor
of Fire Protection Equipment

Contact our Technical Services team to identify
the ideal solution to your specific need—
no matter what the challenge.

reliablesprinkler.com/tunnels

DSI Underground

Reinforcing Progress - DSI Tunneling LLC.

Our future begins underground. From providing the commodities on which everyday life depends, to creating the spaces, transport conduits, and communications networks that connect our world, mining and tunneling are vital to human progress. As ground support specialists, and a proactive partner to underground operations everywhere, we're the people that make it all possible.



We have been a leader in the underground support business in North America since 1920. Our core product line ranges from steel ribs and liner plates to injection chemicals, anchors, bolts, and pre-support systems. We design and develop technically sophisticated Tunneling Systems; offer technical planning with integrated customer support and produce in house to ensure the availability of our systems and our special equipment - anytime and anywhere.

Each support system is customized and professionally engineered to your specific application. Our ground support systems are designed to make tunneling safer. Thanks to our local presence around the globe, we can satisfy your needs for ground control quickly and efficiently - no matter where you are. Our customized products and systems are just in time delivered to service our customers.

Wherever you are in the world, whenever you need us, we'll be on the ground - and beneath it - to reinforce your operation and drive you deeper, further, faster.

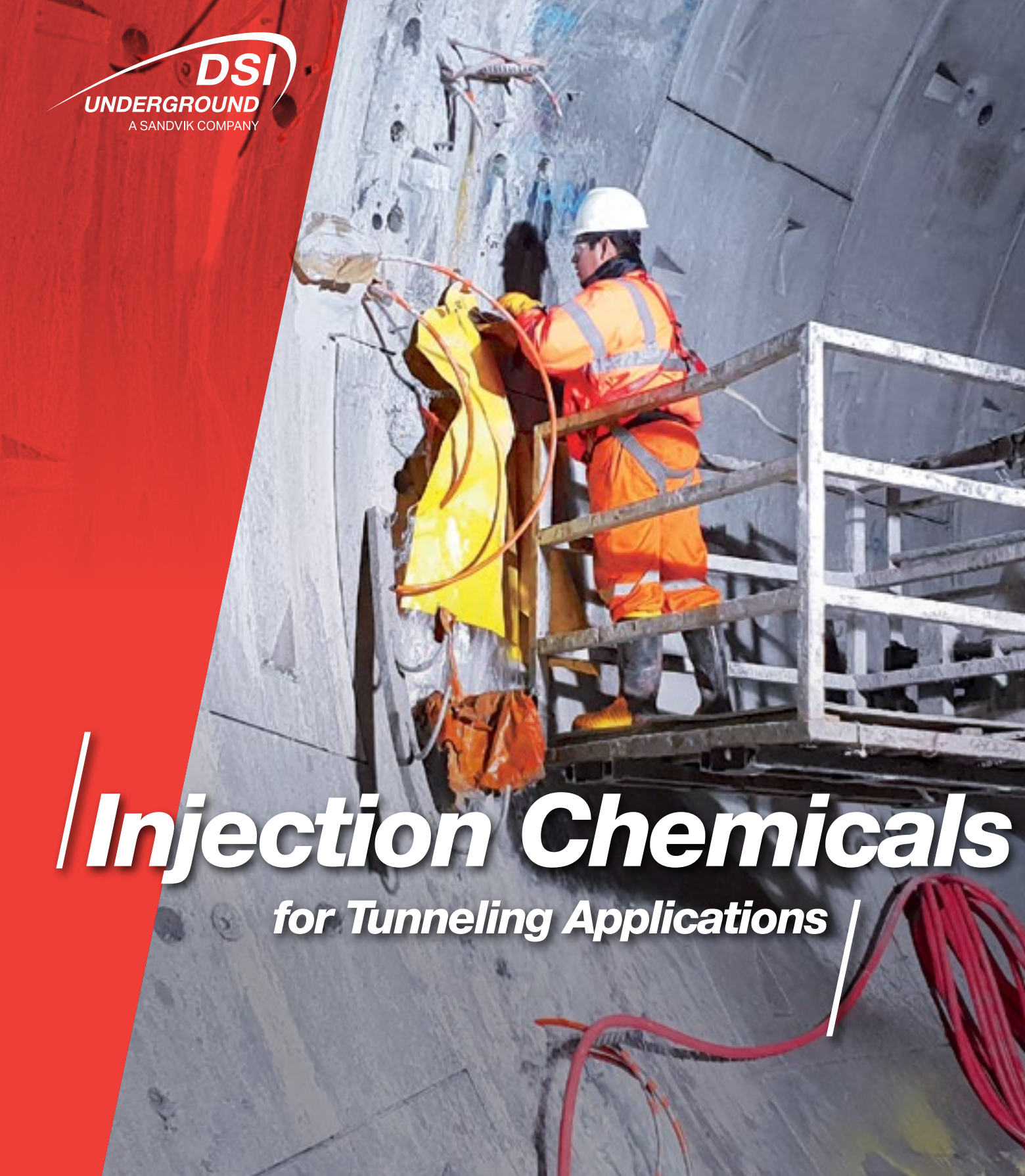
You want to advance your operations efficiently. To improve safety. To minimize downtime and maximize productivity and performance. We have the people and the products for every challenge, and a supply chain you can rely on to deliver. Working alongside you, we help you progress towards your objectives - quickly, reliably, cost-effectively.

When you're tackling a seemingly insurmountable objective, facing tons of rock and earth, and need the skills and knowledge to achieve it, we're with you. We understand the complexities and considerations, the depths, and dangers far below the ground - and we work with you to navigate them, taking you downward and forward, efficiently and intelligently, safely and sustainably. By helping you progress, we're helping our society progress. Which is why it all begins underground. Together, we can help you advance into the earth - and into the future.

DSI Tunneling LLC. Reinforcing progress.



www.dsiunderground.com
502.473.1010



Injection Chemicals

for Tunneling Applications

We design and develop flexible and safe ground support products, that are produced in house with high quality standards and norms. To provide only the best quality to our customers we are continuously monitoring our products and systems. Our product portfolio includes Resin Cartridges, Silicates, Acrylic, Polyurethane Resins and Phenolic Resins.

DSI Tunneling LLC
502-473-1010

dsitunneling.com
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Miller Contracting

MILLER has the ability to sink shafts conventionally from 16' diameter and larger to depths of 1,600' or greater. We utilize nontraditional mucking methods that give us an edge on both safety and productivity. We own two raise bore machines with the capacity to do shafts as small as 48" diameter with our Atlas Copco 73R and as large as 26' diameter with our Herrenknecht RBR400 and up to 2,400' deep. We offer steel lining or cast in place concrete lining. We also offer pilot hole guidance to ensure tight tolerances are attained on hole deviations for elevators, man and material hoist, or emergency escape hoist applications. A MILLER shaft is not just another hole in the ground, it is a finely crafted structure that the owner can use and be proud of! Please give us the opportunity to do one/another one for you!

At MILLER, we strive to bring the best value to our customer's projects. With fair prices, superb service, and outstanding quality, all delivered by an honest hard-working team of professionals. We are committed to seeing that our values are a part of every project we do. We strive to practice the highest levels of integrity with all persons involved and praise God in every interaction.

Please contact us with all your shaft needs! email- Jake Welch jwelch@millercontracting.us or Matthew Miller matthew@millercontracting.us or call them at the office- 618.994.4616 -Jake ext. 115 or Matthew ext. 103



MILLER

MILLER is a family owned and operated company that was founded in 2001. We started out doing residential, light commercial, and agricultural concrete. With our location in the Illinois Coal Basin, we soon had opportunities to do projects in coal mines. Since then we have shifted our focus entirely to the industrial and mining sectors. Today we have projects across the United States, reaching 21 states but are always looking to add states and countries and are in all types of mining! This includes salt, limestone, trona, frac sand, and coal mines, as well as heavy industrial construction for aluminum plants and other manufacturing facilities.

Our high quality contracting services include: shafts, fans, hoisting, complete portals, foundations, and declines. As well as custom projects to meet each customers particular needs. We are an innovative company that approaches each project with an out-of-the box attitude aimed at efficiency, higher quality, added value, and safer job sites.

Our most important resource is our people and and we believe there is no "I" in "Team".



At MILLER, we strive to bring the best value to our customer's projects. With fair prices, superb service and outstanding quality delivered by an honest and hard-working team of professionals, we are committed to seeing that our values are a part of every project that we do. We strive to practice the highest levels of integrity with all persons involved and praise God in every interaction.

for more information please visit our website: millercontracting.us

SENTINEL SOLUTIONS - LET US BUILD YOUR MASTER PLAN

Sentinel was founded in 2016 with the specific goal of bringing the Geotechnical and Underground Construction markets superior equipment and engineered fluid solutions. Our expertise in solids control along with our mud engineering allows Sentinel to provide a true turnkey fluid solution on any project. We bring a high level of field experience coupled with a history of equipment manufacturing which allows us to deliver the right equipment to each project we service.

OUR EQUIPMENT



Shaker Systems



Centrifuges



Auto Dewatering System

Sentinel's focus and dedication to the geotechnical and underground construction industry have impacted our equipment designs and created the most mobile and agile fleet in the US. This market specific design gives Sentinel customers the ability to utilize this separation equipment in tight locations and even on short term projects without the need of pole trucks and cranes to rig up and mobilize.

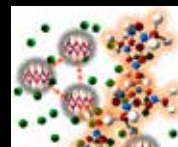
OUR PRODUCTS



Bentonite Products



Polymer



Dewatering

As a full-service mud company, Sentinel's various locations maintain a full suite of drilling fluids and additives. From bentonite and PHPA/PAC polymers, all the way through to dewatering chemistries and solidification reagents.

OUR SERVICES

- Drilling Fluids/Additives
- Dewatering Chemistries
- Solidification Reagents
- Solids Control Equipment
- Custom Equipment Manufacturing
- Fluid Engineering Services
- Screens and Consumables

Sentinel Solutions
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chuck.skillman@sentinel-solutions.com
555 Furrows Road, Holtsville, NY 11742
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**SENTINEL
SOLUTIONS**
EQUIPMENT, SOLIDS CONTROL, DRILL FLUIDS



YOUR TURN-KEY AUTHORITY FOR EQUIPMENT, SOLIDS CONTROL, AND DRILL FLUIDS

Northwest Laborers-Employers Training Trust – Safety and Hazard Awareness for Tunnels (SHAFT) program

The Safety and Hazard Awareness for Tunnels (SHAFT) program, developed by the Northwest Laborers-Employers Training Trust with input from a team of industry experts and stakeholders, is comprised of a blend of classroom discussion and interactive use of materials and mockups.

The curriculum offers comprehensive safety training for both new and experienced tunnel professionals; classes focus on tunnel safety, rail, and utilities.

The training facility, located in Elma, Washington, features a TBM mockup, rail, and access to 1,400' of 12' diameter tunnel – providing students with a unique educational experience.



Northwest Laborers-Employers Training Trust
+1 (800) 240-9112 www.nwlett.org

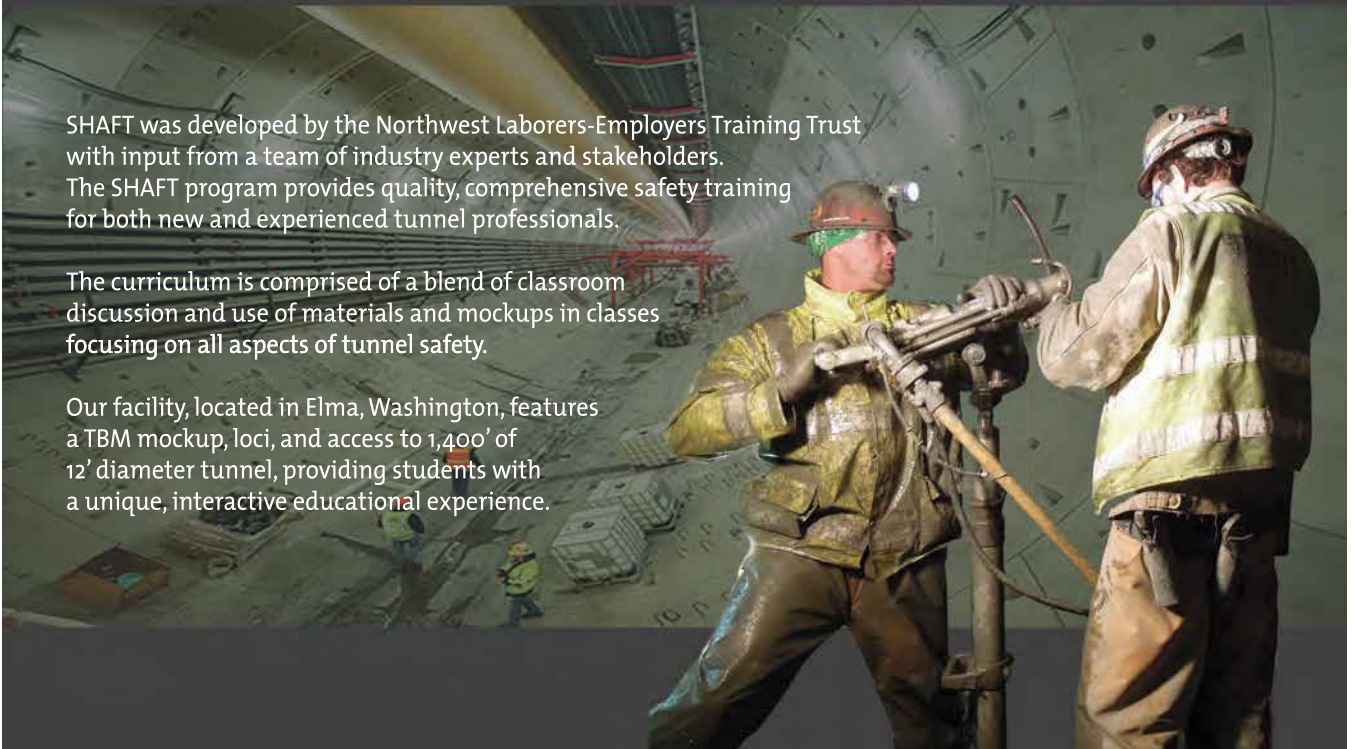
Northwest Laborers Training
nwlett.edu/SHAFT



SHAFT was developed by the Northwest Laborers-Employers Training Trust with input from a team of industry experts and stakeholders. The SHAFT program provides quality, comprehensive safety training for both new and experienced tunnel professionals.

The curriculum is comprised of a blend of classroom discussion and use of materials and mockups in classes focusing on all aspects of tunnel safety.

Our facility, located in Elma, Washington, features a TBM mockup, loci, and access to 1,400' of 12' diameter tunnel, providing students with a unique, interactive educational experience.



Drill Tech Drilling & Shoring, Inc.

Drill Tech Drilling & Shoring, Inc. is a recognized leader in the foundation and excavation industry in the United States. The same guiding principles that helped Drill Tech become a top 10 Foundation Contractor, according to ENR's Top Specialty Contractors, can be seen in Drill Tech's Mining & Tunneling Division (DTM&T).

On the Barrick Range Front Declines, DTM&T has almost completed over 18,000 feet of twin declines almost six months ahead of schedule. Rock conditions varied in strength along the decline and while the contract was initiated using Roadheader excavation methods, DTM&T has utilized both drill & blast and roadheader techniques to overcome these varied rock strengths. Throughout the execution of the work, DTM&T focused on building a safe project ahead of schedule that met the quality expectations of Barrick. Drill Tech's efforts were recognized by Barrick and additional work was issued to Drill Tech's contract.

In addition to the twin declines, DTM&T performed contract work for other contractors on the project site that included Mass Excavation of 129,314 CY of rock and the application of 15,995 CY of shotcrete. During the course of these projects, DTM&T has performed safely for 814 days.

For more information, please visit www.drilltechdrilling.com, email us at dtts@drilltechdrilling.com or call at 925.978.2060
Drill Tech Drilling & Shoring, Inc.
2200 Wymore Way
Antioch, CA 94509





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Kiewit

As a construction, mining, and engineering leader, Kiewit is a FORTUNE 500 company consistently ranking in the ENR's Top 10 Contractors. Kiewit is owned by active employees, creating a level of motivation that keeps the company on top. Kiewit, through its operating companies, brings a wealth of diverse resources and track record for delivering the highest quality results – on budget and on schedule. Our size and experience provides the stability, predictability, and knowhow our clients and partners expect – and the flexibility and overall best value they deserve.

Kiewit has built some of the most complex tunneling and underground projects for more than 75 years. We self-perform soft ground and hard rock TBM tunneling, along with conventional tunneling techniques such as SEM and Drill and Blast, and trenchless technologies such as MTBM and HDD. As one of North America's largest and most respected construction and engineering organizations, Kiewit's underground capabilities offer clients unique advantages to navigating complex, challenging projects from engineering and design, through construction.

We're hiring. Go to kiewitjobs.com to learn more.

**Kiewit**

Kiewit Infrastructure Co.
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Omaha, NE 68102
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Mining Equipment Ltd.



Mining Equipment Rolling Stock for Columbus, Ohio

"Rolling for more than 35 years"

Mining Equipment continues to supply the tunneling and mining industries with top-quality rolling stock, Jetair fans and steel ventilation ducting, as well as a large inventory of rebuilt equipment such as scooptrams, trucks, drill jumbos and other underground gear.

Mining Equipment is based in Durango, Colorado, with a main shop facility in Farmington, New Mexico. They also have steel fabrication capabilities near Shanghai.

Mine Hoists International, a sister company of Mining Equipment, is based in North Bay, Ontario. They boast the world's largest inventory of used mine hoist and large capacity stage winches for mining and shaft sinking projects. Their new 20,000 square foot shop in North Bay, Ontario can handle the largest of hoist and winch rebuilds.



Mining Equipment 10 Ton Locomotives for Columbus, Ohio

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- > JETAIR VENTILATION SYSTEMS
- > MINE HOISTS & STAGE WINCHES
- > METALLIANCE MSVs
(NORTH AMERICAN, GERMAN DEALER)

Normet - Defining the Future Underground.

The underground future built on three pillars, which highlight our expertise and focus:

1. Securing a safe and sustainable future – means building the safest places underground while minimising the impact to the environment and is committed to exceeding industry standards.
2. Innovating for Performance – means delivering productivity with leading-edge solutions and technology.
3. Partnering for the Future – means that our whole team is committed to our customers' goals, and we build capacity for agile cooperation.

We work in close collaboration with our customers. The process expertise amassed over thousands of mine and tunnel projects all over (and under) the globe translates into experience and expertise about what should and should not be done to achieve the optimum results. We utilise our process expertise into concrete actions and financial results for our customers.

Normet has a broad underground offering:

- › Equipment for concrete spraying and transport, explosives charging, scaling, lifting, installation works, and logistics.
- › Construction chemicals for sprayed concrete, admixtures for

all types concrete, injection systems for rock improvement and water control, reinforcement systems for high deformation conditions, spray applied waterproofing systems and needed chemicals for Tunnel Boring Machine (TBM) technology covering hard rock, Earth Pressure Balance (EPB), open face and slurry type machines,

- › High quality and innovative rock reinforcement products that reduce the risk and consequences of accidents and facilitate high productivity in challenging rock conditions.
- › Services for underground mining and tunnelling, including for example spare parts, rental equipment, remanufacturing and upgrades, performance and field services.

Normet has delivered over 14,000 built-for-purpose underground machines which are serviced and supported with a broad service portfolio.

Normet currently employs over 1600 business professionals with a passion for doing "big" things for its customers and for the industries which the company serves.

Normet is a Finnish company operating globally with over 50 locations in 33 countries worldwide. This breadth allows rapid response and reliability to all customers whenever and wherever in the world they may be. Company revenue in 2020 was over 300 M€.

normet
NORMET.COM

THE RIGHT EQUIPMENT FOR EVERY JOB

SPRAYMEC 8100 VC

- › State-of-the-art concrete spraying machine for medium to large-sized tunnel profiles
- › High volume compressor and concrete delivery system
- › Unmatched dosing system and concrete spraying pump technology
- › Available with optional SmartSpray boom automation system or SmartScan system for concrete thickness measurement and documentation

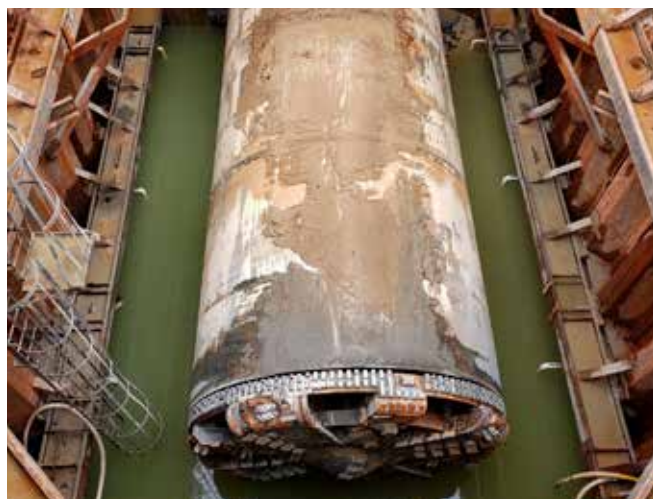
Available in all emission classes and Normet SmartDrive battery-electric version

BARNARD

Whether we're tunneling through the mountains of northern British Columbia or below the streets of downtown San Francisco, our people arrive at projects determined to do the best for their communities and be the best in the industry. We self-perform heavy civil and underground construction including TBM tunneling, drill and blast, and sequential excavation methods. Our work also encompasses power transmission, dams and reservoirs, pipelines, and environmental construction. We have built our reputation on skill, innovation, reliability, safety, and our ability to complete projects on budget and ahead of schedule.

This work has been conducted under a wide range of contracts, including one of the first Progressive Design-Build tunnel projects in the US, the Silicon Valley Clean Water Gravity Pipeline Project in Redwood City, California. On the Lake Mead Low Lake Level Pumping Station Project, a CMAR contract for Southern Nevada Water Authority, our project team was onboard from the Early Contractor Involvement phase and through construction. Our teams stick with projects from start to finish, serving on a bid team and then heading into design or directly to the field to construct the project they've bid. We live where we work and know our projects personally. We build for People.

For more information, please visit our website,
www.barnard-inc.com.



Our underground experts like the fact that there is nothing straightforward about building a tunnel.

STRATA MACHINE VISION SYSTEMS – AI SENSORS FOR TAG-FREE COLLISION AVOIDANCE

Strata SafeSITE HazardAI sensors are machine-mounted intelligent vision systems that employ edge computing and advanced deep neural networks to identify objects in close proximity and work to prevent incidents and collisions.

All-in-one HazardAI artificial intelligence collision avoidance sensors detect and differentiate between people, vehicles and other objects in close proximity to operating machinery and use stereoscopic 3D vision (improves the accuracy of depth perception) to measure distance to the person or object. Collision avoidance algorithms analyze the potential for collision, and automated alarms warn all parties if danger is detected. A display screen installed inside the operator's cab provides camera visuals of the surrounding area and identifies the object and its distance from the machine.

SafeSITE HazardAI requires no pedestrian wearables, such as tags or PADs, nor any vehicle-mounted receivers. AI sensors can be installed on the front, rear and/or sides of machinery and multiple sensors can be used on a single vehicle.

Strata's HazardAI is ISO21815-compliant for full Level 9 implementation. This means that the AI system can be interfaced into the equipment controls to automatically slow or stop machinery without operator intervention. This capability ensures the highest level of safety while working around machinery.

mySafeSITE Platform

All interactions, alarms and incidents are recorded and logged on a comprehensive AI platform. Users can elect for notifications to be sent to supervisors and managers via text or email, ensuring they remain aware of all incidents when applicable. Comprehensive views of critical metrics and site status enables managers to track data and manage HSE reporting.

The Strata family of HazardAI sensors gives site managers confidence that workers and heavy machinery will be kept at safe distances while effecting true long-lasting safety-based workforce behavioral change via the SafeSite AI platform.

For more information please
email us at:
info@strataworldwide.com.

[www.strataworldwide.com/
tunneling](http://www.strataworldwide.com/tunneling)



Artificial Intelligence Machine Vision Systems

SafeSITE™



HazardAI™



AMERICAS

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T: +1-770-321-2500

SafeSITE™ HazardAI™ sensors deliver proven, safety-based Workforce Behavioral Change that keeps workers out of harm's way and management aware of incidents.

www.strataworldwide.com

AKKERMAN: COMMITTED TO EXCELLENCE

Incorporated in 1973, Akkerman will be celebrating our 50th year as one of North America's leading and most-trusted manufacturers of online and grade trenchless equipment.

Founded in 1963 by D.H. Akkerman to support his own contracting efforts, Maynard Akkerman continued to drive corporate growth and innovation. Today, Akkerman is a third generation company that produces multiple products lines to support the trenchless industry.

Akkerman offers small town values coupled with a global perspective. Our business operates with the highest level of integrity and all Akkerman employees have a personal

investment in our customers' success. Akkerman takes pride on our ability to manufacture high-quality trenchless products using American made materials with dedicated employees. For the past 50-years, Akkerman continues to support American jobs that ensure safety, quality, and reliability. We design, manufacture, and assemble all of our equipment in Brownsdale, Minnesota, USA.

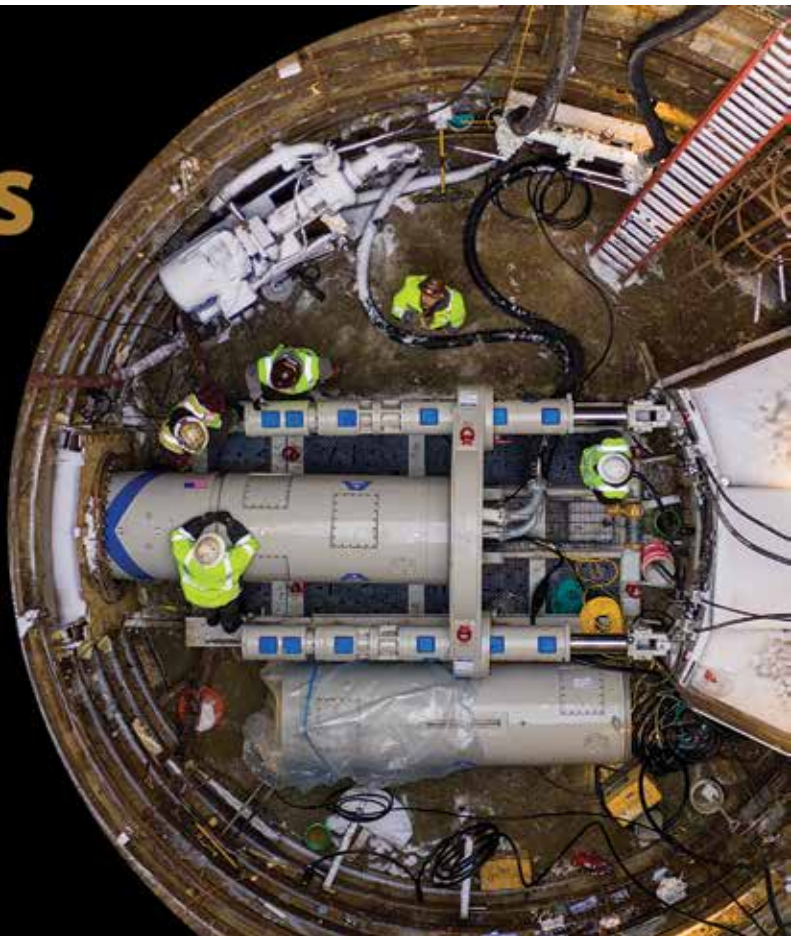
Since nearly 98% of trenchless projects are funded through tax payer dollars, supporting American companies and their workers will stimulate additional infrastructure funding through tax revenue. This investment will strengthen the U.S. economy and further support future infrastructure projects. Akkerman will continue to support American trades by sourcing the highest quality raw materials, components, and supplies.

Contact us at (800) 533.0386 to discuss your next project and visit akkerman.com.



REDEFINING TRENCHLESS SOLUTIONS

- Guided Boring Systems
- Microtunneling
- Pipe Jacking
- Sliplining
- Tunneling
- Earth Pressure Balance



What Makes a CAB® Product Special?

Each and every CAB® Product ordered supports the mission of the Cambria County Association for the Blind and Handicapped which is to develop and support an environment for persons with disabilities which promotes vocational and employment training, independence, and community involvement through rehabilitative, recreation and low-vision services, and education for the prevention of blindness.

Your orders also enable us to provide vision services to our local community.

CAB® Products range from durable hooks and hangers to custom sewn safety products to high visibility reflectors and streamers. We offer a variety of products for the tunneling, mining, pipeline, marine, and solar industries.

We are thankful for each of our supportive and amazing customers!



Cambria County Association for the Blind and Handicapped

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Ebensburg, PA 15931
(814) 472-5077

Johnstown Division
211 Central Avenue
Johnstown, PA 15902
(814) 536-3531

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Brookville

BROOKVILLE 27-Ton MSHA Permissible Locomotives Boosting Safe Work Environment at Major Los Angeles Tunneling Project

Brookville Equipment Corporation (BROOKVILLE) recently shipped three 27-ton MSHA-permissible tunneling locomotives to the Walsh-Shea Corridor Constructors for use on the Crenshaw/LAX Transit Corridor Tunnel Project in Los Angeles. By design, the locomotives reduce the risk of explosion due to geological conditions that may host the presence of methane and other combustible gases. Cal-OSHA has classified the tunnel drives on this project "gassy", mandating the use of MSHA permissible locomotives.

The 27-ton locomotives' special safety features include air start, an enclosed engine block, an exhaust filtration system, wiring and piping guards, and an intake flame arrestor, among other upgrades, to fully comply with MSHA's permissibility requirements. Featuring an 8.3L Cummins six-cylinder diesel engine and four-speed transmission, the 185-horsepower locomotives operate on 36-inch rail gauge underground for Walsh-Shea Corridor Constructors.

"BROOKVILLE was selected based on past performance, simplicity of operation and diagnostics, their ability to communicate locally with MSHA, and knowing we would be dealing with the good people of Brookville, PA, U.S.A.," said Walsh-Shea Corridor Constructors Tunnel Construction Manager David Girard, P.E.



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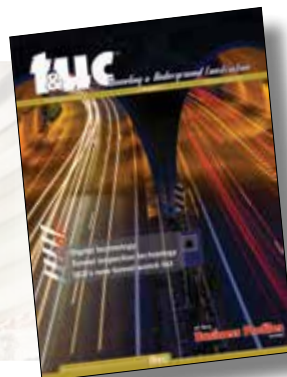
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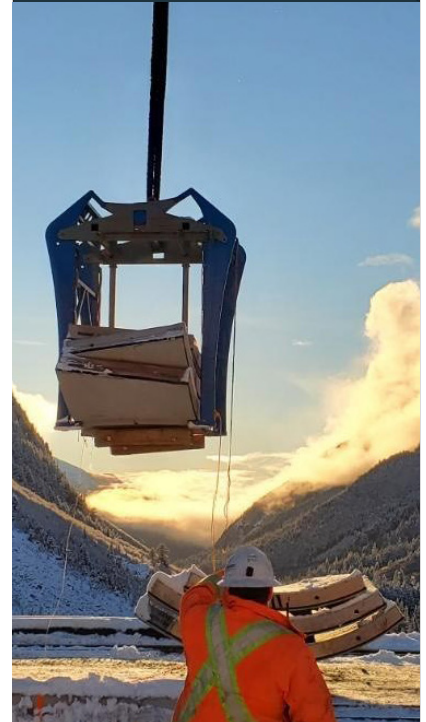
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With the most recent completion of the LIRR Grand Central Madison, we congratulate the MTA on this significant milestone and are proud to be part of the program accomplishments from its early design stages through construction, ready for operation and beyond.








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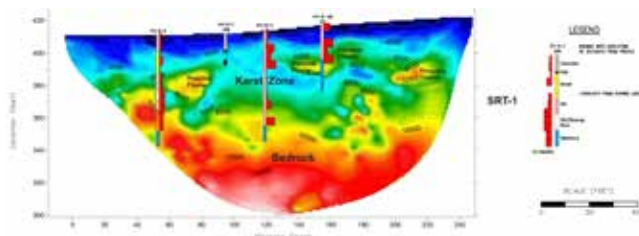
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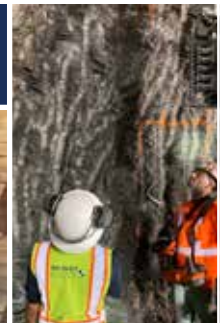
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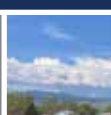
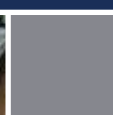
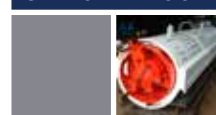
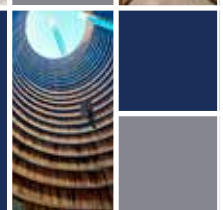
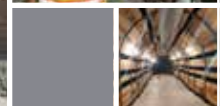


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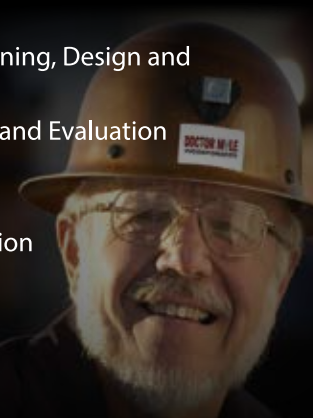
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