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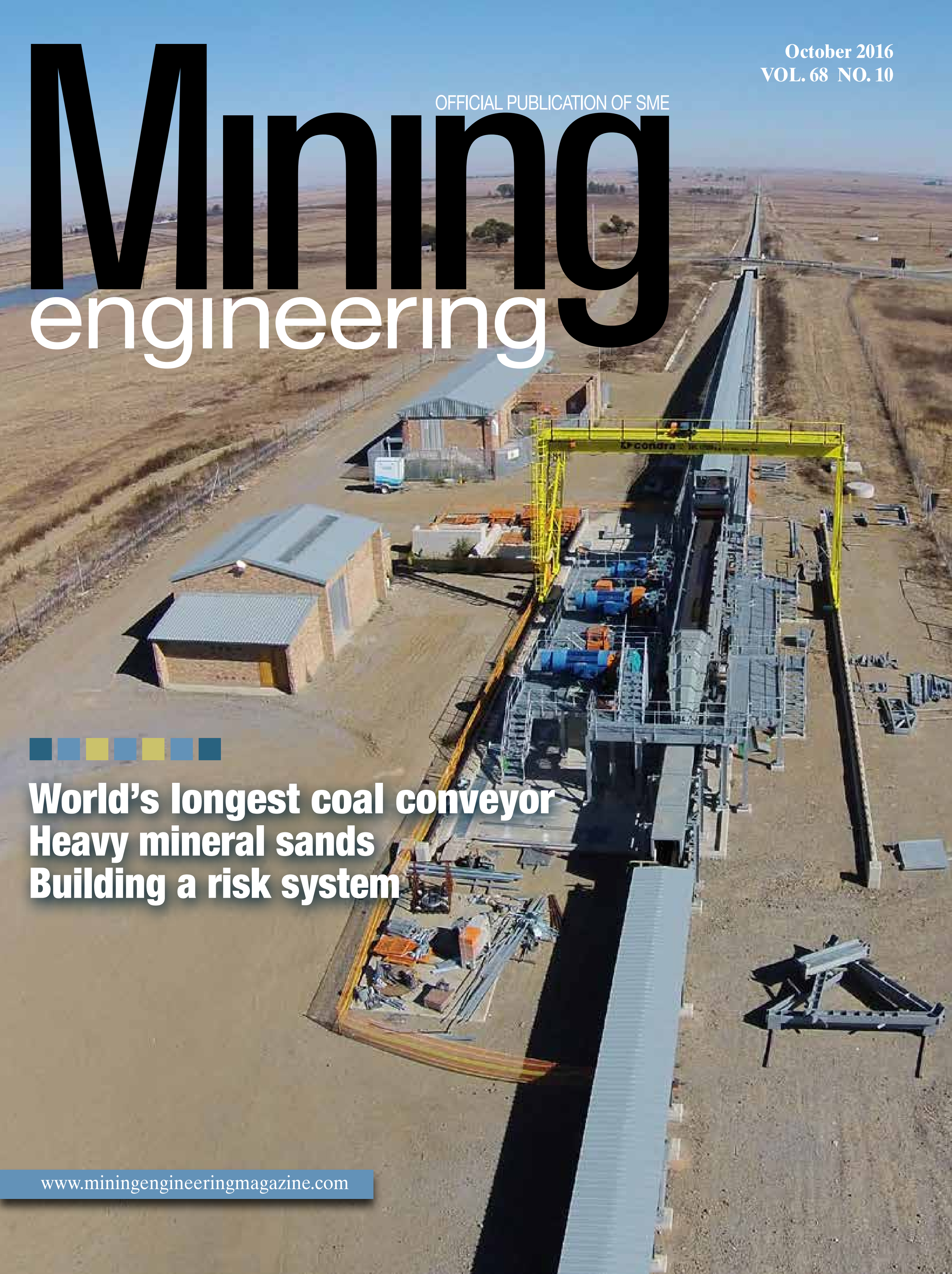

World's longest coal conveyor
Heavy mineral sands
Building a risk system

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Cover Story
Conveyor Dynamics Inc. designed the longest coal conveyor in the world at the Impumelelo Mine in South Africa. It is 26.8 km (16 miles) long. Michael Thompson and Andrew Jennings, of CDI, explain how the project went on page 14. Ancient and modern coastal deposits of heavy mineral sands are the principal source of several heavy industrial minerals, with mining and processing operations on most every continent. Several authors from the U.S. Geological Survey discuss the global significance of these heavy mineral sands, beginning on page 36. Most mining companies have safety programs in place. But are they effective? Building and executing an effective risk management system is discussed on page 44. Cover photo courtesy of CDI.

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Creating a culture of safety:
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Plus: Follow all of the recent news and developments from around the world, including:
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Some wounds never fully heal;
Make safety a value to avoid the scars that last a lifetime

Tim Arnold
2016 SME President

I spent a lot of my mining career as an hourly worker. I have been a graveyard shift laborer replacing rail along the main haulage, worked as an electrician for a year, (even though I knew virtually nothing about electricity), and I am proud to say that for a brief period I "made it" working as a contract miner in a track drift, advancing the headings with a jackleg and a 12B mucker. That was in a time when, if you called yourself a miner before you had proven yourself to the crew, you would get your lamp busted out on the cage going down. I have been on bull gangs, nipped, sunk shaft and even been greased (some of you will know about the last one).

I have many scars from my time as a miner. My first scar came on my first job, where I was on a shotcrete crew as an operator and a laborer. We had to add accelerator to the shotcrete so it would dry faster. The pH of the accelerator was above 11, so it was rather caustic. One afternoon the 55 gallon drums of accelerator could not be delivered to the machine, so we had to carry it to the machine in five gallon buckets. With no lids. Over uneven ground. Needless to say, I slopped a bunch of it down my boot.

I had my fairly new jeans tucked into my boots, and at the end of the shift my calf was itching like crazy. As we were waiting for the ride out of the mine, I pulled the top of the boot down. My leg was literally smoking. The shift boss, understanding just a little chemistry, told the crew to hold me down, and he poured vinegar on my leg. Good thing he told the crew to hold me down, I would have killed myself bouncing off the drift. To this day, I have an indention on my calf from that impromptu chemistry experiment, and it took a couple of years for the blue dye from the jeans to work its way out of my skin.

Photo from cabproducts.com.

My next scar was when I was working as an electrician. You have probably seen these orange hangers that hold up electrical cables in an underground mine. Back then, the end of the hooks were sharp, not rounded as they are now. Placing these hangers was tedious work, up and down a ladder, over and over again. In some places though, the back of the drift was low enough that if you jumped really high, you could snag one end on the wire mesh, and you didn't need the ladder. As you are all probably guessing by now, you could also snag an electrician with the hook on the other side of the hanger. Imagine, for a moment, a chubby electrician momentarily hanging from the back of the drift, one end of the hanger firmly attached to the wire mesh and the other end firmly attached to the meat between my thumb and first finger. That incident left a small scar that you can still see today.

"On Feb. 5, 1997, Rick Smith, miner, age 35, was fatally injured in a fall of ground at 6 a.m. Smith had seven years of mining experience, all at this operation." The partial conclusion of the U.S. Mine Safety and Health Administration

(Continued on page 12)

Safety share: • The U.S. Department of Labor's Mine Safety and Health Administration (MSHA) issued a drill entanglement safety alert to the mining community urging drillers to consider the following before beginning drill operations:

- Examine the drill and surrounding work area.
- Eliminate all tripping hazards.
- Do not wear loose-fitting or bulky clothing when working around drilling machinery.
- Avoid using objects that could entangle in – and be thrown by – moving or rotating parts.
- Stay clear of augers and drill stems in motion.
- Never manually thread the drill steel while the drill head rotates.
- Drill from a position with good footing and access to the controls.
- Assure that machine controls and safety devices such as emergency shutdowns operate effectively.
- Never nullify or bypass machine control safety equipment.
- Place emergency shutdown devices – such as panic bars, slap bars, rope switches, two-handed controls – in easily accessible locations.

Submitted by MSHA

Twin Metals files suit for mineral lease renewal

TWIN METALS HAS filed a lawsuit in federal district court in Minnesota in response to the announcement from the U.S. Bureau of Land Management (BLM) that it would not automatically renew the mineral leases held by Twin Metals for the ore deposits next to the Boundary Waters Canoe Area Wilderness (BWCA).

The BLM was supported in April by the U.S. Department of the Interior, which issued the opinion that the BLM has the discretion to deny renewal of the mineral leases for the underground copper-nickel mine. The decision echoed environmental concerns expressed by Gov. Mark Dayton (D), and denying the leases would likely prove fatal to the $2.8 billion mining project.

In a statement released Sept. 13, Twin Metals, a subsidiary of the international mining conglomerate Antofagasta PLC, said, "An essential component of Twin Metals' mineral rights is its entitlement to nondiscretionary renewal of these leases. The government has long recognized this renewal right."

The company noted that uncertainty over the project "makes it impossible for Twin Metals to engage in any long-term planning, investment, development and operational decisions, effectively thwarting any development of the mineral estate, materially harming the future mining project and jeopardizing Twin Metals' $400 million investment to date."

Moreover, the company said, the federal government's action "appears to be motivated by political pressure and unsupported allegations about potential impacts of future mining development in the region."

The BLM's decision to not automatically renew the leases was supported by environmental groups and other opponents of the proposed mine.

However, the *Minneapolis Star-Tribune* reported that there is a lot of support for the mine as well. It is seen by many as a way to save communities on the Iron Range that have been devastated by a slumping world market for iron ore and massive layoffs. Supporters argue that Twin Metals should be allowed to proceed with its exploration and present a plan for mining that would get the same kind of environmental review as other projects.

The mineral leases thatTwin Metals acquired from other mining companies that explored the area have been in place since the mid-1960s, long before current federal environmental laws took effect. They've been renewed twice without additional environmental reviews or public hearings.

But in February 2016, Dayton came down on the side of environmentalists when he announced that he would not grant the company access to state lands for its project. ■

Bolivia cracks down on mining cooperatives

BOLIVIA ANNOUNCED that it would crack down on mining cooperatives by returning contracts signed between them and private companies to state control.

The decision is in response to the murder of Deputy Interior Minister Rodolfo Illanes who was found beaten by the side of a road hours after he had approached mining protesters to talk over their concerns.

Reuters reported that miners in Bolivia have been demanding increased rights to work with private companies, relaxed environmental restrictions and more subsidies. At least two miners were killed in clashes with police in the run-up to the murder.

President Evo Morales has accused the right-wing opposition of encouraging the protests to foment discord, and his socialist government hit back with tighter restrictions for co-operatives.

Five decrees were agreed on after an emergency cabinet meeting, Mining Minister Cesar Navarro said at a press conference.

They include "reverting to state control those areas in which contracts have been signed between mining cooperatives and private companies," he said.

Bolivia's mining sector is dominated by 120,000 miners working for about 1,700 cooperatives, who have received tax concessions and other benefits from the government in recent years.

They have 31 contracts with private firms in force, according to the mining ministry.

Former deputy mining minister Hector Cordova told *Reuters* the ruling should not affect large companies, which have contracts with state miner Comibol.

He added, "Those smaller companies who joined with cooperatives to take advantage of tax breaks and other benefits will see their interests decrease."

A company called Manquiri is among those listed as having two contracts with cooperatives. It operates a silver mine and is a subsidiary of U.S. firm Coeur Mining, according to Coeur's website.

One of the largest foreign-owned mining companies in Bolivia is San Cristobal, which extracts silver, zinc and lead and is owned by Japan's Sumitomo. A spokeswoman for San Cristobal said it did not use cooperative contracts.

The Morales government nationalized Bolivia's natural gas industry soon after taking power in 2006 and is in arbitration with Glencore over the return of some assets, but it has said San Cristobal would not be nationalized.

Other measures announced include a state audit of cooperative mining areas and the banning of the use of explosives at demonstrations. ■

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Two new coal mines could open in 2017;
Ramaco eyes metallurgical coal mines as prices recover

AN EXCLUSIVE report from *The Associate Press* published on Sept. 6 tells the story of one coal mining company bucking the recent trend of mine closures to instead invest in the startup of two mines.

According the *AP*, Kentucky-based Ramaco's partnership, along with two private equity firms, is planning a $90-million investment in two new metallurgical coal mines and related facilities in West Virginia and Virginia next year. The mines could create as many as 400 jobs, Ramaco chief executive officer Randall Atkins said.

The Elk Creek Mine, in southern West Virginia, and the Berwind Mine, spanning the boundary between southern West Virginia and Virginia, will be operational for around 17 years. Test mining at both sites should begin by early next year, and work on the Elk Creek Mine's coal preparation plant will start even sooner, according to Ramaco.

The company plans to begin talking with potential buyers and could begin shipping coal under supply agreements in 2018, he said.

Ramaco also has been seeking to open a mine in northern Wyoming that would supply coal to power plants for generating electricity. The Brook Mine proposal has been challenged in court by another company claiming surface ownership rights in the area, but the mine faces no significant regulatory obstacles yet.

All of this flies counter to what has been happening in the global coal sector for the past year in which the industry's major companies, including Alpha Natural Resources, Arch Coal and Peabody Energy, have turned to bankruptcy reorganizations.

Ramaco is debt-free and will strive to keep costs down, Atkins said.

"If we can control costs, the market will take care of itself. So even when you had a very low point in the market — which frankly we've had in the past 12 months — our cost is such that we would still be quite profitable," Atkins said.

Very thick coal seams will help control costs at the mines, which will be mostly underground but will include some surface and longwall operations as well, he added.

Ramaco has been working on development, planning and permitting at Elk Creek since acquiring the property in 2012. The company acquired the Burwind property in 2015, Atkins said.

Long-term, Ramaco seeks to produce up to 4 Mt/a (4.4 million stpy) from the two mines.

Prices for high-quality U.S. metallurgical coal have fallen in recent years, from $300/t ($275/st) to below $100/t ($90/st). But they recently rebounded to around $140/t ($127/st) amid production cuts in China, rising demand in India and supply interruptions in Australia, said James Stevenson, director of North American coal for analyst firm IHS.

A metallurgical coal mine in Alabama, formerly owned by bankrupt Walter Energy, is set to reopen under new owner Warrior Met Coal and, in Australia, Pembroke Resources is looking to open a new mine (see page 12).

New life for metallurgical coal mining could become a trend if companies can lock in contracts at higher prices, Stevenson said. ■

Newswatch contents

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12 Possible new coal mine in Australia

13 Newmont named top in sustainability

Gold King Mine site added to
National Priorities List for Superfund cleanup

THE U.S. Environmental Protection Agency (EPA) took a key step toward cleanup at the Gold King Mine and 35 other sites in the Bonita Mining District in southwestern Colorado by putting them on the National Priorities List (NPL) for Superfund cleanup.

The Bonita Mining District NPL will consist of 35 dormant mines, seven tunnels, four heaps of tailings and two study areas located along Mineral Creek, Cement Creek and the Upper Animas River.

These are among 10 new sites nationwide targeted for cleanups — dependent on Congress providing funds. The federal Superfund program involves investigating and cleaning up the nation's worst environmental disasters to protect human health and the environment, *The Denver Post* reported.

"Listing the Bonita Peak Mining District on the National Priorities List is an important step that enables EPA to secure the necessary resources to investigate and address contamination concerns of San Juan and La Plata Counties, as well as other downstream communities in New Mexico, Utah, and the Navajo Nation," EPA regional administrator Shaun McGrath said in a prepared statement.

The formal designation had been expected, and preliminary work at the Gold King has begun. ■

Arch Coal plans to exit bankruptcy;
Company will have to set aside collateral to replace self-bonding

ARCH COAL WILL replace its use of self-bonding and instead set aside collateral to cover future mine cleanup costs as part of its bankruptcy reorganization plan, according to a court filing.

Reuters reported that the plan would end Arch's use of self-bonding, a controversial federal exemption that the largest U.S. coal companies have used for decades. Self-bonding exempts companies from posting bonds or other securities to cover the cost of returning mined land to its natural state.

Arch had $485.5 million in self-bonds in Wyoming when it filed for bankruptcy protection in January, saddled with $6 billion of debt. It must now replace all of its self-bonds within 15 days of its bankruptcy exit plan becoming effective.

Environmental groups that have waged legal battles to hold coal companies accountable for their cleanup obligations welcomed the news.

Arch had initially resisted replacing its self-bonds, arguing in court filings that providing other forms of guarantees would eat into its liquidity.

As the coal sector fell into decline with lower demand from China and increased competition from other energy sources, self-bonding became a more prominent issue. The U.S. Office of Surface Mining and Reclamation Enforcement has asked state regulators to crack down on self-bonding following Chapter 11 filings by some of the largest U.S. coal companies.

Peabody Energy Corp, Alpha Natural Resources and Arch had a combined $2.2 billion in self-bonding liabilities when they filed for bankruptcy over the past 13 months.

Peabody, which filed for bankruptcy in April with $10 billion of debt, has $1.14 billion of self-bonds in four states.

In July, Alpha agreed to replace its self-bonds in Wyoming with other guarantees as part of a complex deal to exit bankruptcy but will continue to cover reclamation at former mine sites in West Virginia with self-bonds. ■

Correction

Table 1 on page 45 of the August issue of *Mining Engineering* did not include the correct header row. The full table is now available online at www.me.smenet.org. ■

Possible new coal mine in Australia;
Pembroke Resources looks to open Olive Downs project

PEMBROKE RESOURCES, a private equity-backed firm, announced that it plans to build a new metallurgical coal mine in Australia's Bowen Basin in 2017.

The company, led by the ex-boss of Gloucester Coal Barry Tudor, said it expects the Olive Downs project to start up within 12 months with a 1-Mt/ (1.1-million-stpy) mine and add two more mines by 2019.

"We'd like to get it into production as soon as possible, but we're not trying to pick peaks in the market," Tudor told *Reuters* in an interview.

Backed by U.S.-based Denham Capital, Pembroke bought the Olive Downs project from U.S. coal giant Peabody Energy and China's CITIC Resources for A$120 million ($92 million) plus an agreed royalty earlier this year, *Reuters* reported.

That's a fraction of the $2.4 billion boom price that BHP and Mitsubishi Corp., paid in 2008 to buy the nearby, still undeveloped, New Saraji metallurgical coal project, which has a similar-sized resource.

The news of a new coal mine in Australia comes as Ramaco Development announces its own plans to open a pair of metallurgical coal mines in the United States (see page 10).

At full tilt of about 14 Mt/a (15.4 million stpy), Olive Downs will be among the largest metallurgical coal mines in Australia, just behind top global exporter BHP Billiton's nearby Peak Downs Mine.

Production costs are expected to be in the lowest quartile due to its large size, high quality coal and proximity to infrastructure. BHP, the world's lowest cost producer, averaged costs of $55/t ($50/st) at its Queensland coal operations in the year to June 2016.

"We assessed this opportunity based on prices at the bottom of the market," said Tudor.

Hard coking coal spot prices have nearly doubled this year to $140/t ($127/st), as high-cost U.S. supply has dropped out of the market and Chinese production has fallen.

Tudor declined to put a price tag on construction but said the first mine, Olive Downs North, would be cheap, as the company would pay a toll for another miner to wash the coal rather than build a washing plant.

Olive Downs South and Wilunga would cost a lot more, but not as much as recent mines such as BHP Billiton Mitsubishi Alliance's $3.4 billion Caval Ridge Mine, as Pembroke plans to ramp up production in stages.

"It would compare very favorably," Tudor said. "It's something we're very confident of being able to fund."

Pembroke is not alone in snapping up metallurgical coal assets from mining giants that are flogging assets to cut debt.

A team led by Taurus Funds Management recently bought Anglo American's 70 percent stake in the Foxleigh Mine, and a consortium led by private equity firm Apollo Global Management is the frontrunner to buy Anglo's Moranbah and Grosvenor mines. ■

President's Page: Focus on safety, some scars never heal

(Continued from page 6)

(MSHA) Accident Investigation Report was: "The accident resulted from the victim being in an unsafe location in relation to the material he was barring down."

I was the underground superintendent at the mine where Ricky Smith was working. He was a co-worker and friend of mine, as well as everyone else at the mine. He was a very likeable man. Very positive and upbeat and one of the hardest working guys on the property. He came in as an entry-level laborer, and distinguished himself as a good worker, willing to jump in and help with anything, any time. Just the type of guy you would want on your crew. He was a "hand." Unfortunately, our last words were not pleasant ones. He was irritated about the events of a company golf tournament, and he left my office angry. It is amazing how clearly I remember every word of that conversation after all these years.

I felt guilty about the accident. What could I have done to prevent this accident from happening? Was our training good enough? Were we tough enough about safety? Were we walking the walk? There were thousands of other questions I was asking myself, and I didn't have any answers. I was not alone. The chief engineer came to me asking the same questions about himself. So did the general foremen, the shift bosses, the chief geologist, the senior engineer, etc. Everyone on the property felt that they had somehow failed. We had. A fatality had occurred on our watch, and he was our friend.

Nobody teaches you about how to deal with a fatality in school. You are on your own, treading on new ground. You learn a lot about character from it. Some people shy away, some step to the front. We all agonized. We all dealt with it in our own way, and none of us was wrong. It is the most difficult thing you will ever experience in mining, and you can never be prepared for it.

So please remember, we must be vigilant about safety.

The scar from the loss of Ricky Smith is deep and long. It runs from the top of my soul to the bottom of my heart. That scar will never heal. ■

Newmont named top in sustainability;

Dow Jones names Newmont as the top in the mining industry

FOR THE SECOND year in a row, Newmont Mining Corp. was ranked by the Dow Jones Sustainability World Index (DJSI World) as the mining industry's overall leader in sustainability. Newmont's inclusion on the index also marked the tenth consecutive year the company has been selected for the DJSI World. This year, the DJSI World — one of the most highly regarded sustainability indices — included 316 global companies identified as leaders in the areas of sustainable economic, environmental and social performance. Newmont was the first gold company named to the index in 2007 and has been included on the DJSI North America Index every year since 2006.

"We're honored that our economic, environmental and social performance was recognized as the best in the mining sector by the Dow Jones Sustainability World Index for the second year running. This performance reflects our team's deep commitment to sustainability and continuous improvement," said Gary Goldberg, president and chief executive officer. "Our focus on creating value and improving lives through sustainable and responsible mining translates into safe working conditions and good jobs for employees; sustainable economic development for our host communities; and strong returns and prospects for our shareholders and other stakeholders."

In addition to being ranked the overall industry leader in the mining sector, Newmont received the highest score (100th percentile) in a number of areas including occupational health and safety, risk and crisis management; climate strategy; environmental policy and management systems; water-related risks; asset closure management and corporate citizenship and philanthropy.

DJSI World tracks the performance of 2,500 leading companies worldwide, independently evaluating their long-term economic, environmental and social performance. DJSI evaluates companies based on a variety of criteria. ■

Impumelelo coal mine
is home to the world's longest belt conveyor

by Michael Thompson and Andrew Jennings

Conveyor Dynamics Inc. completed the Impumelelo conveyor in South Africa. It is 28 km (16 miles) long.

For a third time in its history, Conveyor Dynamics Inc. (CDI) has designed and commissioned the longest conveyor in the world. CDI's first record-setting conveyor was Zimbabwe Iron and Steel Co's 15.6-km (9-mile) overland conveyor between the Ripple Creek Mine and the Orco plant (du Toit & Fletcher, 1997). CDI subsequently surpassed this distance in 2007 with the design and commissioning of the 20-km (12.7-mile) Curragh conveyor near Westfarmers, QLD, Australia (Steven, 2008). The company has built upon the experience and expertise gained from these previous record-setting successes to design and commission the most recent record-setter, a 26.8-km (16-mile) long Impumelelo conveyor near Secunda, South Africa.

Michael Thompson, member SME, and **Andrew Jennings,** member SME, are project manager/principal engineer on the Impumelelo project and president at Conveyor Dynamics, Inc. respectively, e-mail jennings@conveyor-dynamics.com.

The principal contractor for this project was ELB Group (ELB), based in Johannesburg, South Africa. ELB provides engineering services, construction services and equipment supply in the South African market and throughout sub-Saharan Africa.

CDI, based in Bellingham, WA, USA, specializes in the design of long-distance overland conveyors (OLC). The company designs trough and pipe conveyors, transfer chutes and control systems as well as forensic engineering services. The company also develops software for the bulk material handling operations on every continent except Antarctica.

CDI was engaged by ELB to do the basic mechanical engineering design and a large part of the detail design for the Impumelelo overland conveyor. Additionally, CDI provided


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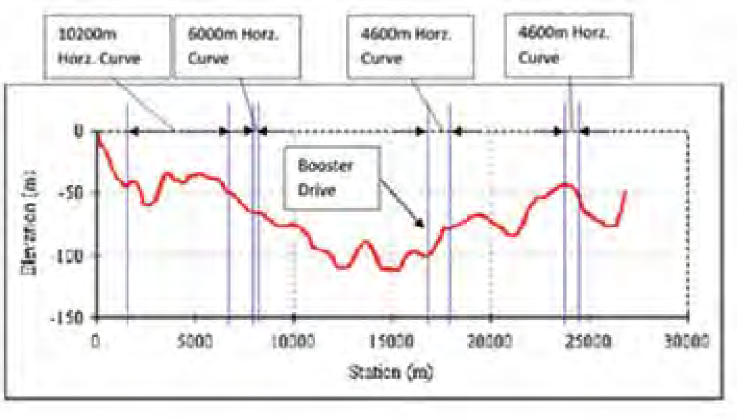
Figure 1

Conveyor profile.



the mechanical design for the principal underground incline conveyor that brings the coal from the underground storage bunker to the mine head storage silos above ground.

Description and location

CDI developed the basic mechanical and control system design with its proprietary in-house software BeltStat and BeltFlex (Nordell & Ciozda, 1984). Figure 1 contains an elevation view of the OLC and Fig. 2 shows the map of the conveyor route. The conveyor runs from the Impumelelo mine site to SASOL's Brandspruit coal-to-diesel conversion plant. It has an overall horizontal length of 26,816 m (87,980 ft), with a total change in elevation between the tail pulley and the head pulley of -50 m (-164 ft).

Except near the tail and head end transfers, the conveyor is at or near ground level for its entire length. The OLC follows the general contour of the local terrain and includes 54 vertical curves and four separate horizontal curves (Fig. 1).

The original route included a transfer tower shown between station 18,000 and 19,000 on the map. This would have resulted in a two-flight conveyor system, with lengths of about 18.5 km and 9.5 km (11.8 and 5 miles), respectively. CDI designed the in-line booster drive and tripper chute station that eliminated the transfer tower. This reduced the cost of the civil and structural works, reduced the visual impact of the conveyor, and increased the conveyor reliability by removing a chute that could have plugged if the 18.5-km (11.8-mile) conveyor took longer to

stop than the 9.6-km (5.1-mile) conveyor.

Design considerations

At peak tonnage, the conveyor transports 2.4 kt/h (2,600 stph) of coal at a maximum speed of 6.5 m/s (21 ft/sec). However, operators can reduce the conveyor speed to save power when they transport less tonnage. The motors are able to start the fully loaded belt at the lowest ambient temperature recorded for this location: -5° C (23° F).

To reduce the operating expense required, CDI specified a special low-rolling resistance (LRR) bottom rubber compound and special low-rolling resistance precision idlers. CDI also designed stringers with long span lengths between idler sets on the carry and return side. The large idler spacing, reduced CAPEX, noise and maintenance time. Idlers from several idler manufacturers were tested to prove they met CDI's low drag and SASOL's low noise specification.

To reduce windborne dust losses and emissions, the entire length of the cover is covered, and the idler tables are specifically designed to shield the carry side of the conveyor belt from the wind.

Project timeline summary.

- November 2012 — Contract negotiations between ELB and CDI finalized.
- February 2013 — Basic mechanical design completed and delivered to ELB.
- December 2013 — Detail engineering completed and delivered to ELB.
- May 2014 — ELB commences construction of Impumelelo overland conveyor. CDI begins programming work for the overland conveyor's motor and brake control system.
- May 2015 — Control system development completed.
- October 2015 — Completion of construction of the overland conveyor by ELB. The conveyor was dry (no load) commissioned with CDI's assistance almost immediately after construction was completed.
- October 2015 — Wet (loaded) commissioning completed by ELB.

Conveyor belt

The super low rolling resistance (SLRR) belt was imported from Aneng, China and produced by Goodyear Veyance (now Contitech). The critical belt parameters appear in Table 1. The belt manufacturer originally offered 500 m (1,640 ft) reels of belt for this project. CDI insisted they manufacture and

Figure 2

Map of Impumelelo conveyor route across Mpumalanga province, near Secunda, South Africa.

transport 1,000 m (3,280 ft) reel and, after review, Veyance agreed (Fig. 3). This increased shipping costs but provided substantial splicing cost and time savings.

The entire belt was pulled and spliced at an average rate of 1 km/day (0.62 mile/day), the installation was performed with the assistance of Conveyor Belt Technologies of Vancouver, BC, Canada and could have been completed

Table 1

Belt specs.

Width	1200 mm
Strength	ST-2000 N/mm
Cover thickness (top x bottom)	7.0 x 5.0 mm
Weight	33.3 kg/m
Total belt length installed	54,033 m
Cable Diameter	5.2 mm
# of cords	86

in 60 days, if the crews had pulled the belt continuously.

Control system

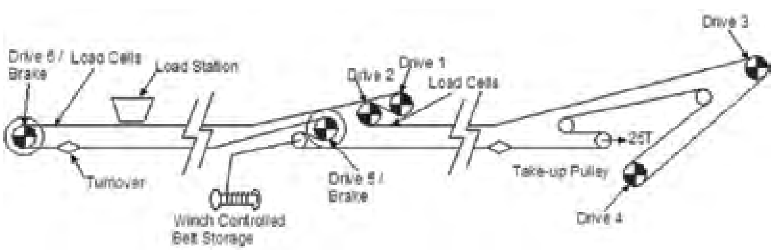
Figure 4 contains a schematic of the system pulley layout. There are a total of 4 x 1,000 kW and 2 x 500 kW (4 x 1,340 hp and 2 x 670 hp) VFD controlled motors at three separate locations: the head, the booster station and the tail. Drives 1-4 are 1,000 kW (1,340 hp) and drives 5 and 6 are 450 kW (603 hp). Belt

Figure 3

1,000 m (3,280 ft) belt reel.

Figure 4

Pulley schematic.



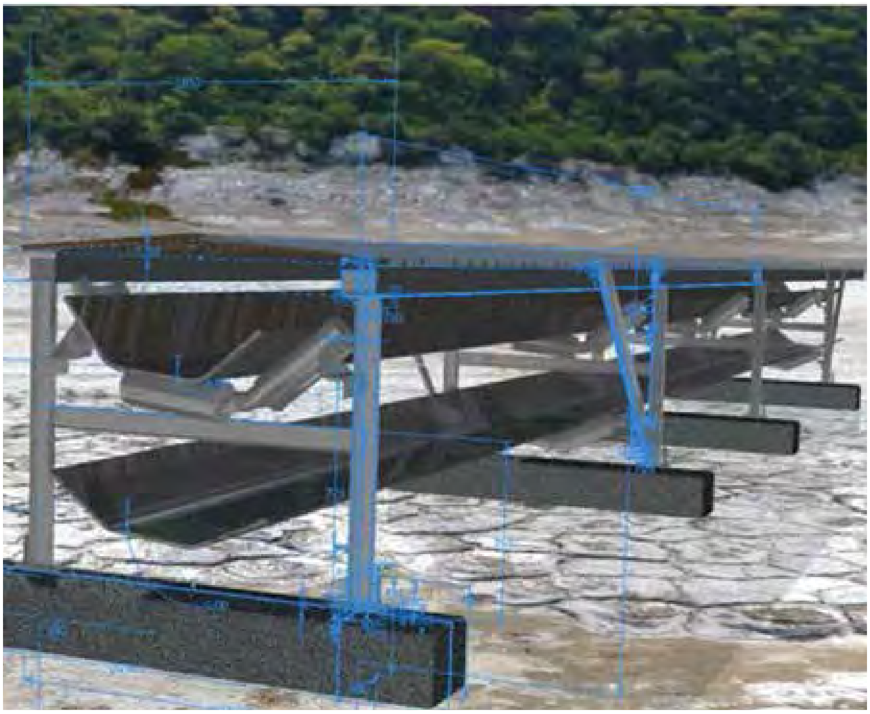
speed, and belt slip conditions are monitored using special analog tachometers designed and manufactured by CDI. (Unlike counter cards, CDI's analog tachometer is accurate for both low and high speeds.) Belt tension for motor control purposes is measured at selected locations using a specially designed array of idlers and strain gauge load cells.

The control system for this conveyor is similar to the control system that CDI created for the Essroc conveyor (Jennings, Perrone, & Cornet, 2013). When the conveyor is running, the torque supplied by Drive 1 and Drive 2 is determined by a belt tension feedback loop. The belt tension is measured by a series of special idler rollers and strain gauge load cells along the carry strand just after Drive 2. Drive 3 is speed controlled and Drive 4 follows Drive 3's torque. Drive 5 follows the torque produced by Drive 6. Drive 6 produces enough torque to maintain a constant tension at the tail.

The OLC accelerates to full speed in 670 seconds, including a 70-second dwell period at 5 percent of full speed. The dwell stretches the belt prior to applying full torque for the main

Figure 5

3-D rendering of Inventor model of idler support structure with banked idlers.



acceleration ramp.

Using a combination of the drives and the brakes, the belt takes 100 seconds to come to a fully controlled operational stop.

Belt stretch is removed by a 22-t (25-st) gravity take-up located at the head end of the conveyor. This take-up incorporates a capstan brake in the take-up reeving to reduce the severity of take-up motion during emergency stops (Jennings, Perrone, & Cornet, 2013). Since the tape length of the belt is 54 km (33 miles), a second take-up, or "belt storage loop," was added to the booster drive station to take up the slack created by permanent elongation out of the belt as it stretches over time. This take-up is static and is only adjusted when the dynamic take-up at the head end is observed approaching its travel limits.

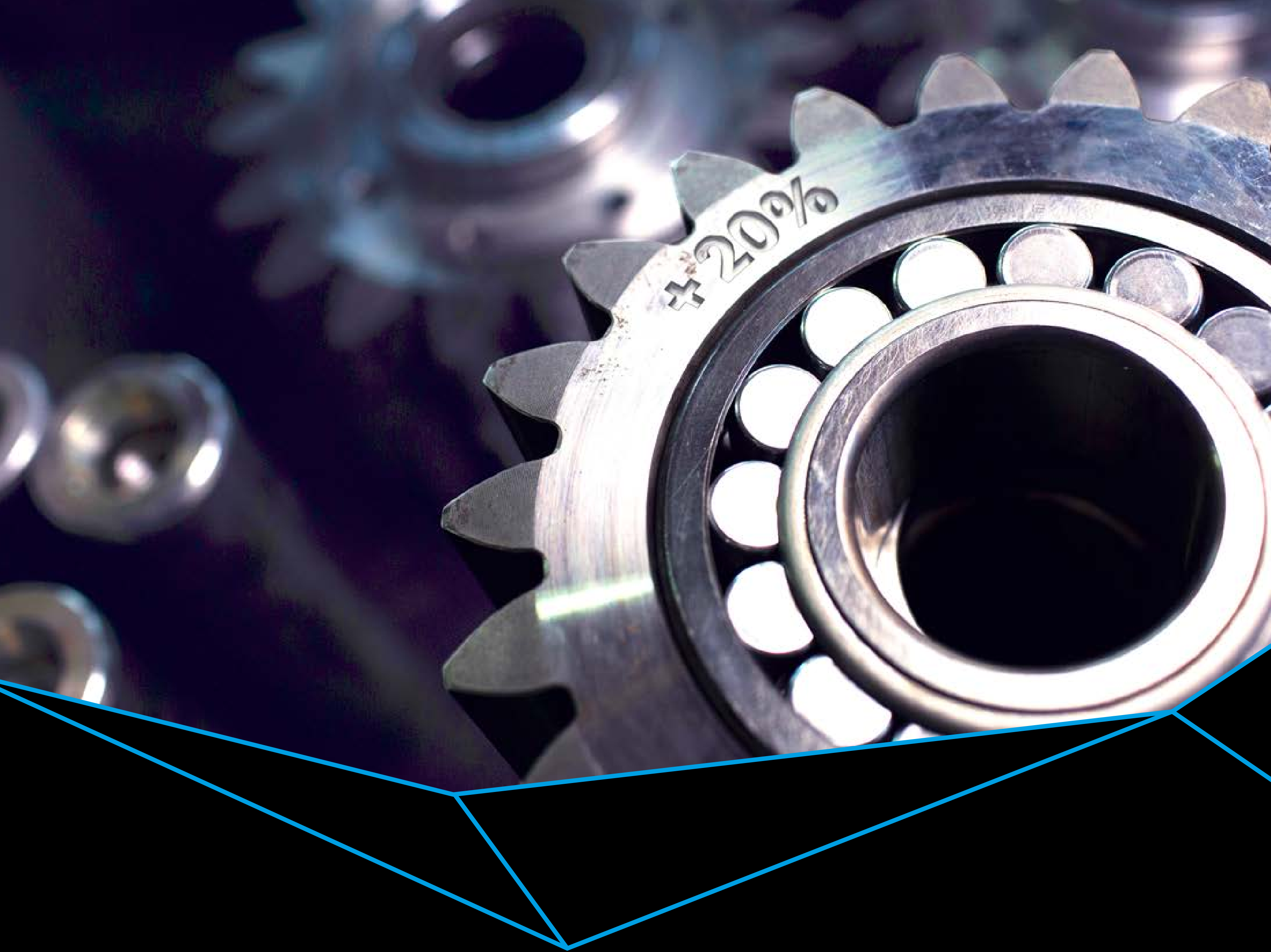

+20%

Figure 6

Idler support structures - as built.

Idlers

The idlers were provided by Lorbrand of Pretoria, South Africa, and were tested by Tunra in Australia to ensure that they met CDI's drag and SASOL's noise reduction requirements. To reduce drag, CDI specified lower viscosity grease than is typically supplied by the idler bearing manufacturers. The idlers consist of a steel inner shell with polypropylene outer covers. The plastic outer covers reduce the idler noise and make it easier to achieve a low TIR, making the idlers roll easier and with less vibration.

The idler spacing was chosen to minimize the idler count while maintaining belt sag at or below 1 percent during normal steady-state running conditions. Due to the large variation in belt tension along the length of the conveyor, it was impossible to find a single idler spacing that prevents belt flap resonance effects. To prevent belt flap, the carry and return side idlers are on a staggered spacing. The carry


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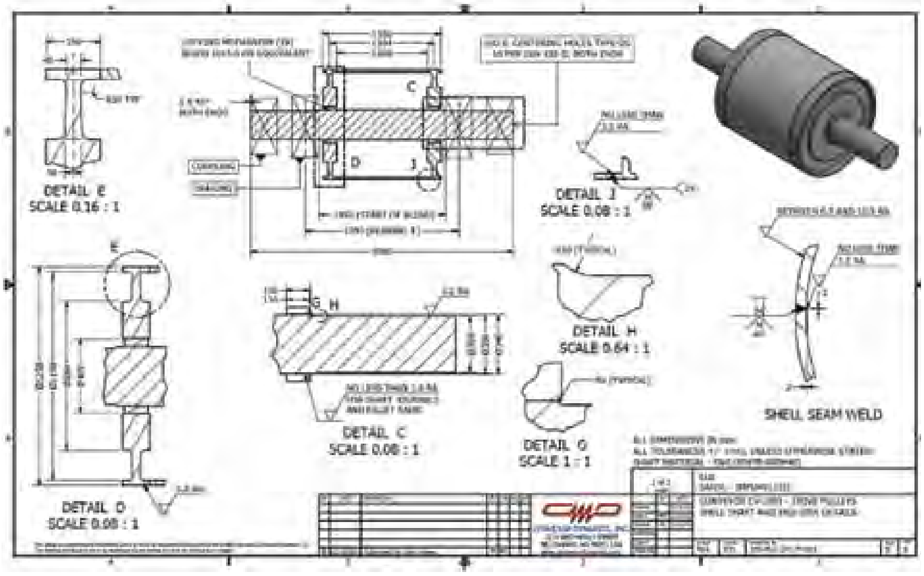
Figure 7

Detail design of drive pulley.



side spacing alternates between 4 m and 5 m (13 ft and 16 ft). The return side spacing alternates between 8.25 m and 9.75 m (27 ft and 32 ft).

Trough angles on the carry side varied between 35º in the straight sections of the conveyor and 45º in the horizontal curves. The return idlers were also troughed at 30º to assist in belt tracking and to further reduce the probability of belt flap.

During the design process, there was some concern about the potential for damaging the belt due to the long idler spacing. CDI has a dimensionless index called the idler junction pressure index (IJPI). Using this index, CDI ensures that its wide idler spacing designs will not damage the belt.

CDI chose an idler spacing that is three times wider than the idler spacing recommended in the handbook published by the Conveyor Equipment Manufacturer's Association (CEMA). CEMA's rules were developed for conveyors that are much smaller than 27 km (16.7 miles). In general, the take-up tension required to avoid drive slip on shorter conveyors is less than it is on longer conveyors. Since the belt tension is lower on shorter belts, shorter belts have shorter idler spacing to avoid excessive sag. Short conveyor designers could increase the take-up tension to resolve their sag problems. But on short belts, increasing take-up often entails increasing belt strength which is more costly than adding additional idlers. On long belts, the high take-up tension required to avoid drive slip allowed CDI to use larger idler spacing without introducing excessive sag. This is one of the many situations where the standard rules did not apply and where CDI's experience optimizing conveyors dramatically reduces the capital expenditure as well as time required to install and maintain a conveyor.

Idler support structures

Figure 5 shows a rendered view of the idler support. CDI provided ELB with detail drawings and structural analysis for this assembly. The idler support structure is identical everywhere along the conveyor except for the elevated sections above the turnovers and drives. This standardization made the manufacture of the 9-m (29-ft) long

Figure 8

FEA analysis of drive pulley.

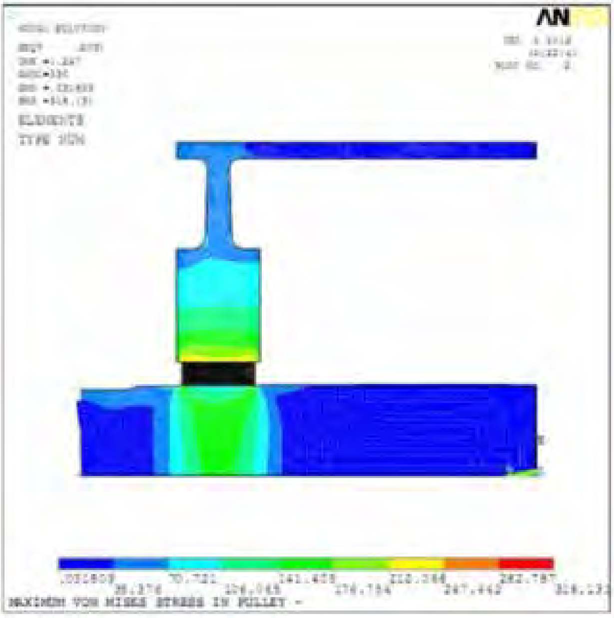
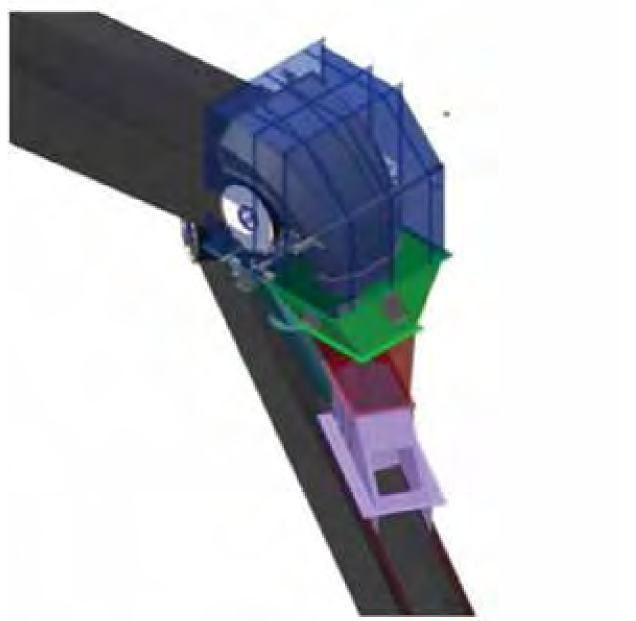


Figure 9

3D model of tail chute.



support structures more cost effective than it would have been if there were different support structures in the horizontal and straight sections of conveyor. After optimizing the structural members with FEA, the weight of the idler support structure was 17 kg/m (excluding the idler frames and hood covers). The structure can support more than 2,400 kg/m, and wind pressures of up to 880 Pa (880 N/m^2).

CDI also provided the majority of the coordinates used to locate each idler support structure along the conveyor route, including adjustments for the anchor bolt connections, and shim pack thicknesses for each idler transom frame. ELB carefully surveyed each support point and erected the structure to within +/- 0.5 mm (Fig. 6).

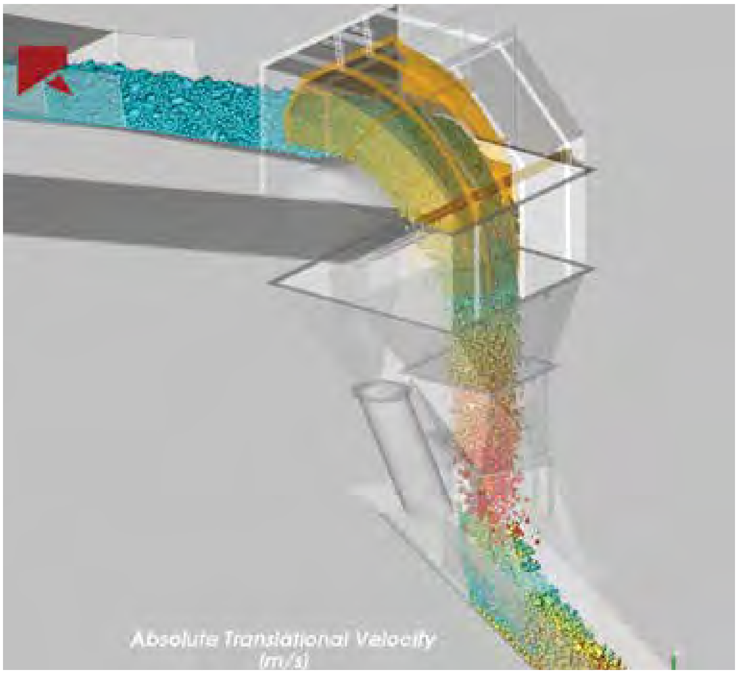
Pulleys

CDI also designed the engineer class pulleys for both the Impumelelo overland conveyor and for the underground incline conveyor (Fig. 7). These pulley designs were severely constrained by the following design considerations:

- Conservative deflection, stress and

Figure 10

DEM simulation of tail chute.



fatigue limits.

- 300 percent motor torque ratings on the shaft locking rings.
- Requirement to use only locally readily available steel shaft material, in order to expedite rapid replacement of pulley shafts.
- EN8 steel material similar to AISI 1040 steel.
- Restrictions on pulley shell diameters created by standardization of pulley sizes and gear reducer ratios at the SASOL plant.

The combination of these constraints resulted in pulley shafts that were larger than CDI would have designed using less conservative stress limits, lower locking ring torques, and higher strength steel for the shafts. This, in turn, limited the amount of flexibility that could be designed into the end disk profiles to reduce the fatigue stresses in the end disks to acceptable levels.

Using CDI's proprietary pulley design software, PStress, CDI was able to quickly iterate through the available design variables to develop a pulley design that met these exacting specifications (Qiu & Sethi, 1993). After arriving at a suitable design, CDI modeled the pulleys with ANSYS FEA package to demonstrate the validity of PStress's calculations (Fig. 8).

Due the complexity of the final pulley designs, CDI reviewed the production operations and quality control procedures of several pulley manufacturers located in Johannesburg to ensure the quality of the fabrication met the design intent. All of the pulley manufacturers surveyed in the process had excellent design, fabrication and quality control, and any of them could have produced these pulleys. ELB selected Lorbrand as the pulley manufacturer, based on CDI's recommendations and other factors.

Chutes

CDI also provided conceptual and detail design and DEM analysis of the tail feeding chute and the booster station tripper chute. DEM simulations were performed with Granular Dynamics International's Rocky DEM software.

The DEM simulation requires a calibration of the material in terms of its bulk density, particle size distribution, moisture content and other factors. Critical factors incorporated into the chute design are the material's natural trajectory and the need to direct the material so that it is correctly centered on the receiving belt. One must also attempt to minimize impact forces (low vertical velocity), and create a tangential velocity that closely matches the belt speed. Proper chute design can prolong belt life by a considerable degree, up to a factor of 10 in some cases (Nordell, Palabora Installs Curved Transfer Chute in Hard Rock to Minimize Belt Cover Wear, 1994).

Figure 9 shows the completed 3-D model of the tail feed chute. Figure 10 shows the DEM simulation of steady-state material flow through the tail chute at the design tonnage.

This chute uses a curved hood deflector to consolidate and direct the material flow toward the center of the receiving belt. A curved receiving spoon takes the impact of the falling material and redirects the flow stream to be tangential to the belt motion. The drop height between the head pulley on the discharge conveyor and the belt determines the material speed as it exits the receiving spoon.

Figure 11 shows the completed 3-D model of the booster station chute. Figure 12 shows the DEM simulation of steady-state material flow through the chute at the design tonnage. The interior of the chute includes two separate impact and material speed control surfaces: an inclined launder section with no curve to keep the material from hitting the belt at low speeds, and a lined hood section with converging sidewalls which reduces the material speed during the drop to the belt and centers the material on the receiving belt.

All the chutes were carefully designed to keep dust entrained in the main material flow and include settling zones where dust entrained in the air settled back onto the belt before the air exhausts into the environment.

Booster station structure

Figure 11 shows the chute end of the booster station structure CDI designed. This design also included an extended ramp to bring the belt line up to the level of the Drive 1 pulley. CDI provided the structure design and determined the foundation loads for

Figure 11

3D model of booster station.

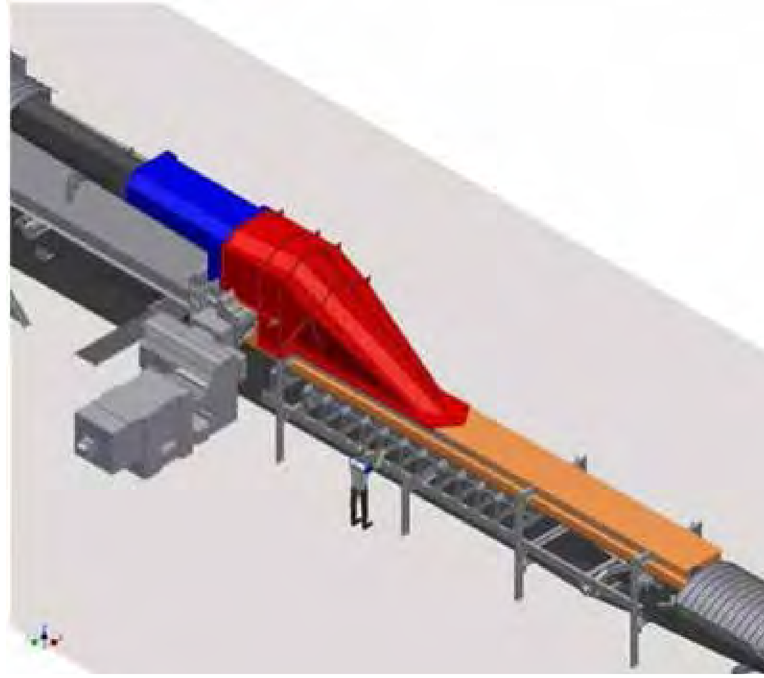


Figure 12

DEM simulation of tripper chute.

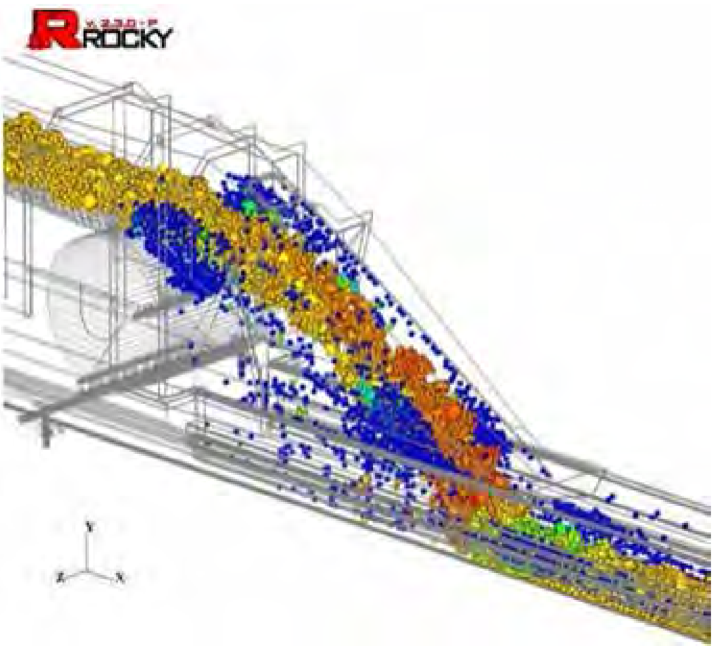
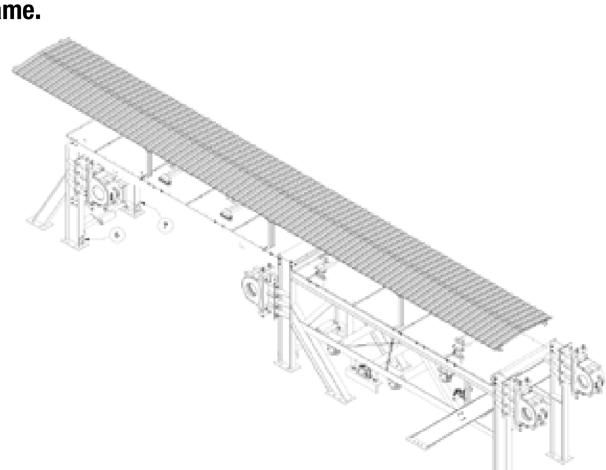


Figure 13

Booster station approach ramp.

Figure 14

Drive frame.



the entire booster station.

CDI sectioned the structural assembly into easily fabricated modules that fit in hot-dip galvanizing tanks, are easy to transport and assemble in the field. The design includes three main assembles: an approach ramp, the drive frame and the skirt board frame.

The "approach ramp" (Fig. 13) is 138-m long x 2.4-m high x 3.8-m wide (453-ft long x 7.11-ft high x 12.5-ft wide), the ramp sits on an inclined slope with a ground level rise of 3.6 m (12 ft). Access walkways were included on both sides of the ramp. The belt storage loop, with its stationary take-up trolley and winch and the rail system it runs on are mounted underneath the ramp.

The drive frame (Fig. 14) is 15.7-m long x 3.3-m tall x 2.2-m wide (51.6-ft long x 11-ft tall x 7.3-ft wide). This structure supports three drives: Drive 1, Drive 2 and Drive 5. It also supports the tail end of the tripper chute.

The "skirt board frame" is 9.2-m long x 2.2-m high x 2-m wide (30-ft long x 7.3-ft high x 6.6-ft wide) (Fig. 15). This structure supports most of the tripper chute weight as well as the skirt board, impact idlers, and the material and belt loads.

Summary

The capital and operating expenses associated with long overland conveyors are substantial. However, significant cost savings are achievable when the designer understands that many of the rules of thumb that apply to short conveyors do not apply to long belts. Long belts differ from short conveyors in several ways including: high tensions that lead to less belt sag, longer time to complete a belt rotation leading to longer belt life, and large operating costs that justify low rolling resistance belting and idlers. The large investment in construction materials and time on long conveyors justifies devoting significant engineering hours to optimizing the conveyor assemblies. Even small differences in ground module weight and erection time lead to large savings when 27 km (16.7 miles) of ground modules are needed.

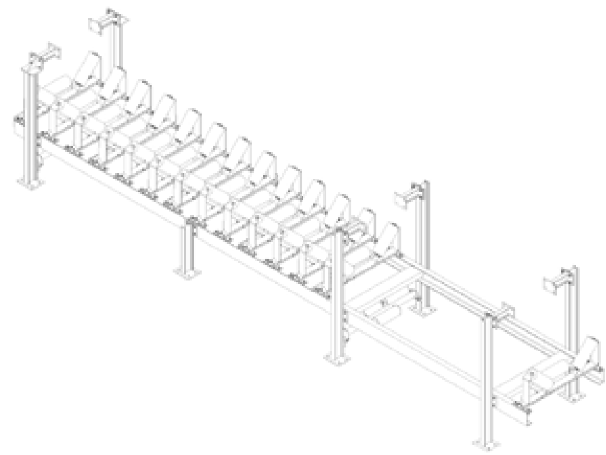
At Impumelelo, CDI utilized the most advanced technology available to optimizing the system. It reduced the number of transfer towers, reduced the structural steel weight, reduced the number of idlers and pulleys, reduced the installation time, cut the operating costs, and improved the availability of the system. CDI also reduced the noise, reduced the visual impact of the system, reduced dust emissions.

This paper highlights the complexity of

optimizing an overland conveyor to maximize the reliability and availability of a conveyor while reducing its cost. It is a flagship for state of the art conveyor engineering that clearly demonstrates the advantages of using modern engineering tools and a strong understanding of the science of conveying to design overland conveyors. ■

Figure 15

Skirt board frame.



Acknowledgments

The author would like to acknowledge the substantial work others contributed to the Impumelelo project including CDI's former president Lawrence Nordell, CDI's Jason Aldrich, who led our drafting team, ELB's project manager Manny Marques, ELB's engineers Douw de Necker and Adi Frittella and Conveyor Belt Technologies' Larry Kuzik who led the team that pulled and spliced the belt.

References

du Toit, E. L., & Fletcher, A. (1997). Zisco Overland Conveyor. BELTCON 9. Midrand, RSA: IMHC.

Jennings, A., Perrone, P., & Cornet, J. (2013). Case study: corrrecting control problmes on Essroc's mulidrive station, horizontally curved conveyor. Transactions of the Society for Mining, Metallurgy, and Exploration.

Nordell, L. K. (1994, Vol. 14 No. 4). Palabora Installs Curved Transfer Chute in Hard Rock to Minimize Belt Cover Wear. Bulk Solids Handling.

Nordell, L. K., & Ciozda, Z. P. (1984, Vol. 4 No. 1). Transient Belt Stresses During Starting and Stopping: Elastic Response Simulated by Finite Element Methods. Bulk Solids Handling.

Qiu, X., & Sethi, V. (1993, Vol. 13 No. 4). A New Pulley Stress Analysis Method Based on Modified Transfer Matrix. Bulk Solids Handling.

Steven, R. B. (2008, Vol. 28 No. 3). Belting the World's Longest Single FLight Convetional Overland Belt Conveyor. Bulk Solids Handling.

Report confirms struggle in coal country;

About 50 percent of jobs in 2011 have been lost in five years

A NEW REPORT FROM Standard & Poor's found that the number of coal jobs in the United States has fallen by nearly 50 percent from its peak in 2011.

The report found that the hardest hit communities were Boone County, WV; Pike County, KY and Campbell County, WY.

The statistics confirm the difficulty that many in the industry have struggled with as the price of coal hit a 30-year low. But the numbers might also suggest that coal companies are adjusting to a new normal, finding a balance with fewer employees and lower production, the report said.

There is uncertainty about whether the drop in employment in places like Campbell County is a short- or long-term phenomenon. The issue hinges on whether this bust is a temporary dip in the commodity cycle or a permanent shift in the way the United States receives its electricity, *The Wyoming Tribune Eagle* reported.

Future restrictions on greenhouse gases underline the fact that coal will face more than just a market battle in the coming decades. That will cut into profits and pose a risk to communities that rely on coal for their livelihoods.

The U.S. Energy Information Administration projections of how coal will weather the Clean Power Plan are not promising.

Under the plan, the administration reports, coal production in the West will decrease by 140 Mt (155 million st) between 2015 and 2040.

Powder River Basin coal, which benefits from its low mining costs and low amount of sulfur, accounts for about two-thirds of that production.

Last year, the West accounted for 55 percent of the nation's coal production. Under the Clean Power Plan, that could drop to 52 percent.

Moreover, natural gas continues to be a major competitor for coal, both in terms of emissions and its relatively cheap price, thanks to new drilling technologies, analysts say.

Despite market pressures, Campbell County remains the strongest producer of the 25 counties in the report, with 46.5 Mt (51.3 million st) of coal mined in the second quarter of this year. That's approximately half what was mined in the fourth quarter of 2011. ■

Coastal deposits of heavy mineral sands; Global significance and US resources

by Bradley S. Van Gosen, Donald I. Bleiwas, George M. Bedinger, Karl J. Ellefsen and Anjana K. Shah

Ancient and modern coastal deposits of heavy mineral sands (HMS) are the principal source of several heavy industrial minerals, with mining and processing operations on every continent except Antarctica. For example, HMS deposits are the main source of titanium feedstock for the titanium dioxide (TiO_2) pigments industry, obtained from the minerals ilmenite (Fe_2+TiO_3), rutile (TiO_2) and leucoxene (an alteration product of ilmenite). HMS deposits are also the principal source of zircon ($ZrSiO_4$), from which zirconium dioxide (ZrO_2) is obtained for uses mostly in refractory products. Sometimes monazite [(Ce,La,Nd,Th)PO_4] is recovered as a byproduct mineral, sought for its rare earth elements, and thorium (Ault and others, 2016; Sengupta and Van Gosen, 2016; Van Gosen and Tulsidas, 2016).

Figure 1

Layers of heavy minerals in quartz beach sand (heavy mineral sands, HMS), Trivandrum, India. Photograph courtesy of B. Hou, Geological Survey of South Australia. (“HMs,” heavy mineral content.)

Bradley S. Van Gosen, Donald I. Bleiwas, George M. Bedinger, Karl J. Ellefsen and Anjana K. Shah are research geologist, physical scientist, physical scientist and research geophysicist and research geophysicist, respectively, U.S. Geological Survey, email bvangose@usgs.gov.

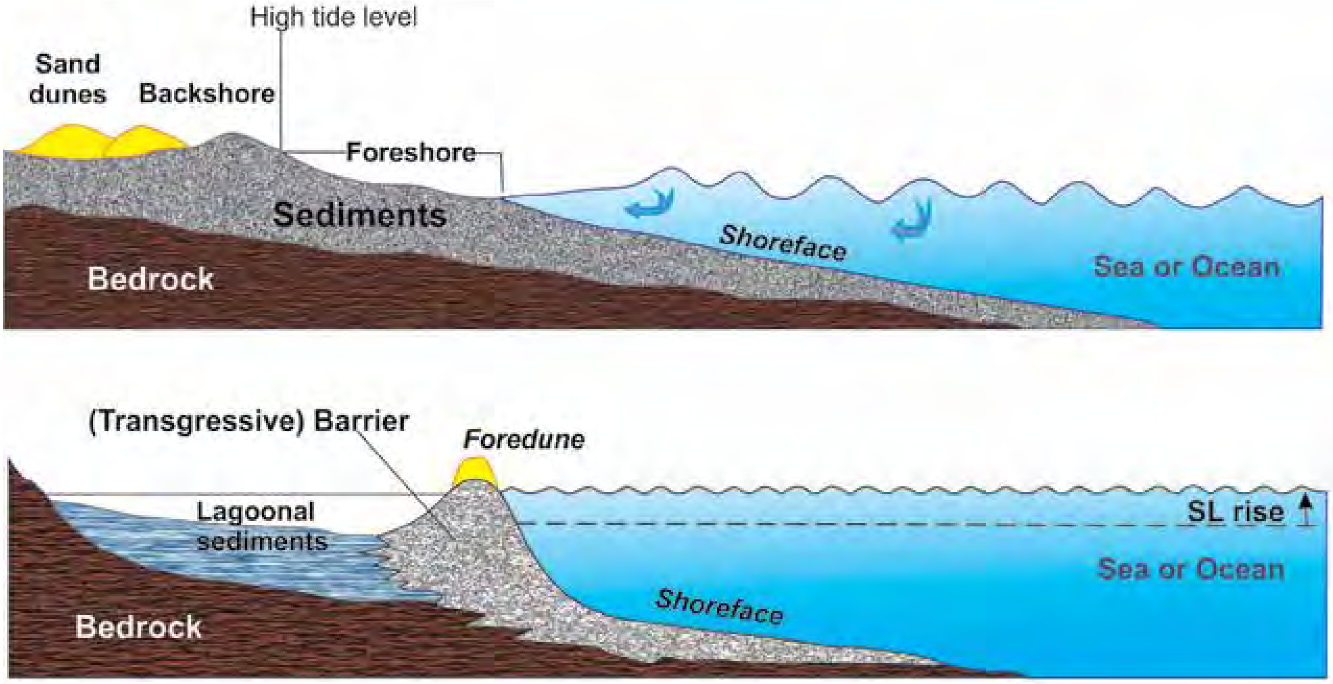
HMS are sediments containing dense (heavy) minerals that accumulate with sand, silt and clay in coastal environments, locally forming economic concentrations of the heavy minerals (Fig. 1). Economic (mined) HMS deposits include Holocene sediments on modern coasts, such as examples in India and Brazil, as well as coastal deposits formed by transgressions and regressions of the seas during intervals in the Quaternary, Tertiary and Cretaceous, such as in Australia and the southeastern United States. Economic deposits typically contain heavy-mineral concentrations of at least two percent.

Individual heavy minerals are commonly defined as minerals with a specific gravity greater than approximately 2.9 g/cm^3. These minerals are generally resistant to chemical weathering and physical degradation and thus survive well in fluvial and coastal environments. Heavy minerals in coastal HMS deposits may include, in order of general abundance, ilmenite, leucoxene, rutile, magnetite, zircon, staurolite, kyanite, sillimanite, tourmaline, garnet, epidote, hornblende, spinel, iron oxides, sulfides, anatase, monazite, cassiterite and xenotime. Of these, ilmenite, leucoxene, rutile and zircon are the primary economic minerals. Garnet, monazite, cassiterite and xenotime are occasionally recovered as byproducts. The heavy minerals as a suite typically make up no more than 15 weight percent of a deposit and usually much less. Quartz and clay minerals form the bulk of the sediment. The geology of HMS deposits and examples of significant districts are summarized in Van Gosen and others (2014) and Hou and Keeling (2016).

To form HMS deposits, heavy minerals are liberated from inland source rocks by weathering and erosion, and the detritus is transported by streams and rivers to coastal areas. Here the sediments are deposited, reworked by the actions of waves, tides, longshore drift and wind. These physical processes sort the light and heavy minerals based primarily on their density, thereby

Figure 2

Schematic cross sections showing the features commonly used to describe shoreline depositional environments associated with heavy mineral sands deposits. Upper cross section: mainland beach depositional environment; lower cross section: barrier-tidal lagoon shoreline depositional environment (modified from Roy and others, 1994). (SL, sea level.)



concentrating the heaviest minerals as layered sediments in a variety of coastal depositional environments (Fig. 1). Typically, approximately 80 percent of the heavy-mineral suite is ilmenite, rutile, iron-oxide minerals and zircon, with lesser amounts of leucoxene, monazite, garnets, sillimanite and staurolite. HMS can accumulate in deltas, the beach face (foreshore), sand dunes behind the shore (backshore area), the offshore (shoreface and farther seaward), in barrier islands (transgressive or regressive barrier) and tidal lagoons (Fig. 2), as well as the channels and floodplains of streams and estuarine channels. These depositional environments are discussed in detail by Hou and Keeling (2016). Processes that one can observe now provide modern analogues to the processes that formed the ancient deposits (Fig. 3). That is, the natural processes that act upon coastal areas today, such as effects of waves, storm surges, tides, longshore drift and sediment supply from inland sources are similar to the processes that formed voluminous deposits of HMS over thousands to millions of years of deposition along ancient shores across the world.

Industrial uses and production of titanium mineral concentrates from heavy mineral sands

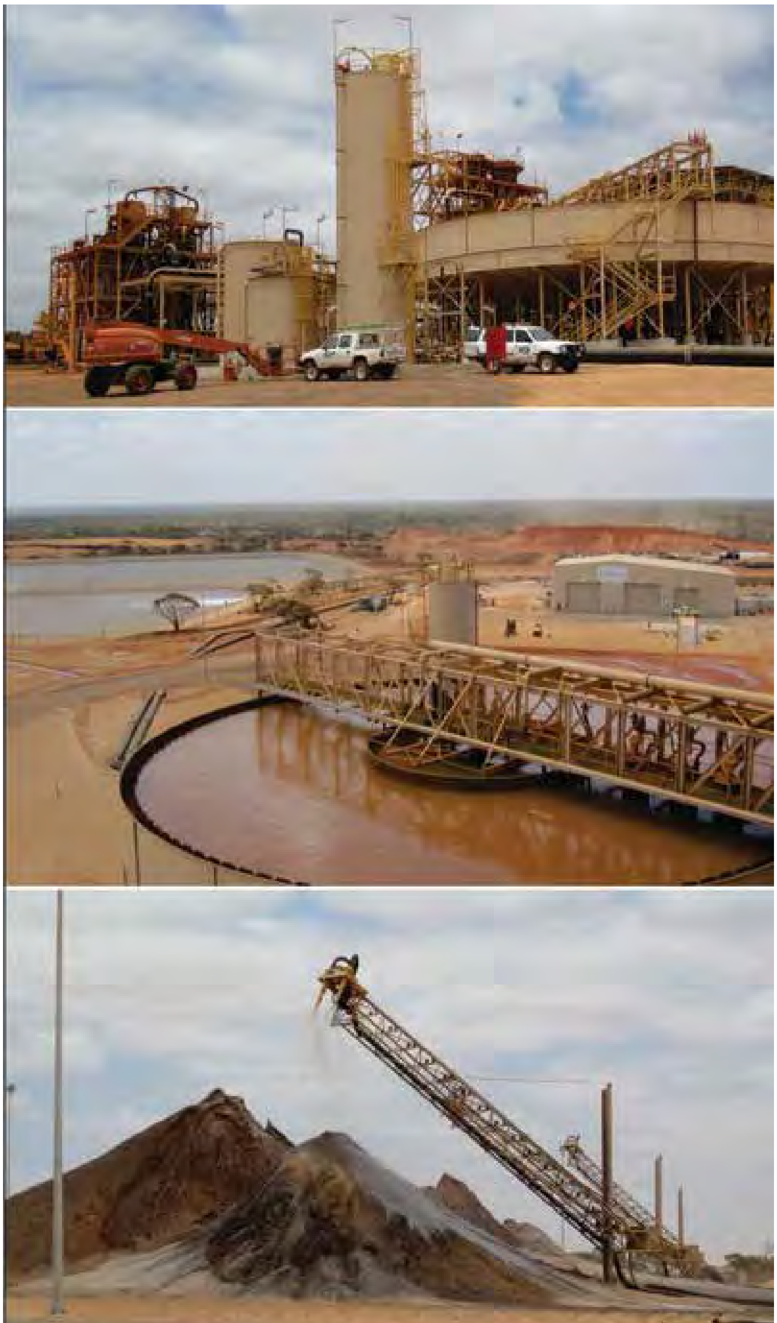
Industrial uses of titanium. Most titanium, derived from processing ilmenite, rutile, and leucoxene, is not consumed in its metal form

Figure 3

Heavy minerals (black sands) deposited on a beach along the shoreline of the Atlantic Ocean in Virginia. Storms can bring heavy minerals from the shoreface to the beach (foreshore), where the actions of waves, tidal currents, and wind can mechanically sort the heavy minerals into layered deposits. Photograph courtesy of Rick Berquist, Virginia Division of Geology and Mineral Resources.

Figure 4

Wet concentrator plant (top), early-stage concentrator that separates clay and silt from the sediments (middle photo), and wet stacking of heavy mineral concentrate (bottom photo); Jacinth operation of Iluka Resources Ltd., located in South Australia. Photographs courtesy of B. Hou, Geological Survey of South Australia.



but as titanium dioxide (TiO_2). In powder form, TiO_2 is a white pigment used in paints, paper and plastics because it provides even whiteness, brightness, very high refractive index and opacity (Woodruff and Bedinger, 2013). On a gross weight basis, 95 percent of the U.S. domestic consumption of titanium mineral concentrates was used to produce TiO_2 pigment in 2015 (Bedinger, 2016a). The remaining 5 percent, mainly from rutile, was used in welding-rod coatings and for manufacturing carbides, chemicals and metal. For example, some rutile and leucoxene is blended to produce high-grade titanium with a TiO_2 content of 70 to 95 percent (HiTi), which is used as a feedstock to produce titanium dioxide, to make titanium metals for the aerospace industry, and to manufacture welding rods (Woodruff and Bedinger, 2013; Bedinger, 2016a). Titanium metal, derived from processing rutile, ilmenite and (or) leucoxene, is also used in spacecraft, guided missiles, jewelry, artificial joints and heart pacemakers. The estimated value of titanium mineral concentrates consumed in the United States in 2015 was $670 million (Bedinger, 2016a).

Production of titanium mineral concentrates. HMS deposits are usually mined by surface operations involving dredging and (or) dry surface mining techniques. Onsite gravity separation operations are used to isolate the heavy-mineral components (Fig. 4), utilizing the density contrasts between the light and heavy minerals by settling out the “heavies” from slurries of sediment-water mixtures. Further processing and separation of the heavy mineral suite is accomplished using magnetic and electrostatic circuits. Ilmenite and rutile are the two principal mineral concentrates for titanium, with ilmenite accounting for about 92 percent of the world’s consumption of titanium minerals.

Ilmenite is typically the most abundant titanium mineral in HMS deposits. It has a TiO_2 content of 53 percent, but intercalation and weathering causes the TiO_2 content to vary significantly. After deposition in sediments, weathering enhances the TiO_2 content of some Ti-oxide minerals. In particular, iron is leached from ilmenite by weathering, which thereby upgrades the TiO_2 content of the ilmenite (Force, 1991). Ilmenite is often further processed to produce a titanium concentrate, either as synthetic rutile or titaniferous slag.

Ideal rutile contains about 95 percent TiO_2, but it is usually less abundant than ilmenite in HMS deposits. Although numerous technologies are used to produce synthetic rutile, nearly all are based on either selective leaching or thermal reduction of iron and other impurities in ilmenite (Bedinger, 2013a).

Dozens of coastal deposits of HMS are being mined and processed to extract heavy minerals, with active operations on every continent except Antarctica, serving as globally important sources of some industrial minerals. For example, in 2001, about 96 percent of the zircon, 90 percent of the rutile and diamonds, 30 percent of the ilmenite and 80 percent of the monazite produced by the global minerals industry was mined from coastal placer deposits of HMS (Chi and Zheng, 2001). More recent data suggest these percentages have remained similar (Australian Atlas of Mineral Resources, Mines, and Processing Centres, 2013). Australia and China are the major global producers of HMS, recovering mainly ilmenite, rutile and zircon, and in the past, monazite (Australian Atlas of Mineral Resources, Mines, and Processing Centers, 2013). Exploration for HMS deposits is occurring in Australia, India, Kenya, Madagascar, South Africa, Sri Lanka, the United States and other countries (Van Gosen and others, 2014).

From 2000 to 2014, the total world mine production of ilmenite concentrates increased by 30 percent, from an estimated 4.3 to 5.57 Mt (4.7 to 6.14 million st) of TiO_2 contained in concentrate (Gambogi, 2002; Bedinger, 2016a). The increase in production of concentrates was brought about, to a large extent, by increased demand by China.

In 2014, China was the leading world mine producer of TiO_2 in ilmenite concentrates, with approximately 960 kt (1.06 million st) representing 17 percent of global production. This was a significant increase from 2000, when China produced about 150 kt (165,000 st) of TiO_2 contained in ilmenite concentrates, less than 5 percent of global production (USGS records). Australia was the world's leading producer of ilmenite concentrates in 2000, which contained about 1.23 Mt (1.35 million st) of TiO_2, about 29 percent of world production. In 2014, Australia produced 720 kt (793,000 st) of TiO_2 contained in ilmenite concentrates, about 13 percent of global production (Bedinger, 2016a).

Other major producers of TiO_2 contained in ilmenite concentrates in 2014, and their respective share of global ilmenite production, were South Africa (11 percent); Vietnam (10 percent) and Mozambique (9 percent) (Table 1). The future market for titanium mineral concentrates is expected to depend on the demand for TiO_2 pigment (Bedinger, 2016a).

World production of natural rutile concentrates increased from about 390 kt (430,000 st) of TiO_2 contained in concentrate in 2000 to 471 kt (518,000 st) of TiO_2 contained in concentrate in 2014 (Gambogi, 2002; Bedinger, 2016a). The increase in production of natural rutile concentrates resulted from the development of mines in Sierra Leone, beginning in 2006. World production of rutile concentrates was less than ilmenite concentrates over the entire period.

In 2014, Australia was the world leader in mined natural rutile production with about 190 kt (210,000 st) of TiO_2 contained in rutile concentrates, a 40 percent share of world mine production (Bedinger, 2016a). This was a decrease from 2000, when Australia produced an estimated 225 kt (248,000 st) of TiO_2 contained in concentrate, about a 58-percent share of world mine production. In 2014, Sierra Leone produced about 100 kt (120,000 st) of TiO_2 contained in rutile concentrates, representing about 21 percent of 2014 global production of

Figure 5

Index map of the southeastern United States showing the distribution of clastic coastal deposits of the ancient and modern Atlantic Coastal Plain. These sediments, ranging from Late Cretaceous to modern deposits, locally contain heavy mineral sands. Also shown are four recent HMS mining areas in this region: the Concord Mine (1) and the Brink Mine (2) of Iluka Resources Ltd in southeastern Virginia; the Mission Mine (3) of Southern Ionics Inc. in southeastern Georgia and the Trail Ridge deposits (4) of The Chemours Company in northeastern Florida.

Heavy Mineral Sands

Table 1

World mine production in 2014. (Ilmenite and rutile reported in thousands of metric tons of TiO_2 contained in ilmenite and rutile concentrates, respectively; zirconium reported in gross weight)

Country	Deposit type	Ilmenite	Rutile	Zirconium
China	HMS	960	nr	150
Australia	HMS	720	190	551
South Africa	HMS	600	53	387
Vietnam	HMS	560	nr	nr
Mozambique	HMS	510	nr	51
Madagascar	HMS	300	9	nr
Ukraine	HMS	250	63	nr
India	HMS	190	17	40
Kenya	HMS	100	22	nr
Brazil	HMS	100	nr	nr
United States	HMS	100	*	**
Senegal	HMS	60	nr	nr
Sierra Leone	HMS	nr	100	nr
Indonesia	HMS	nr	nr	110
Canada	Hard rock	480	nr	nr
Norway	Hard rock	440	nr	nr
Russia	Hard rock	110	nr	nr
Other countries		90	17	130
World total		5,570	471	1,419

natural rutile concentrates (Bedinger, 2016a). Other major natural rutile producers in 2014, and their respective production percentage share of global TiO_2 contained in rutile concentrates, were Ukraine (13 percent), South Africa (11 percent) and Kenya (5 percent) (Bedinger, 2016a) (Table 1).

Industrial uses and production of zircon from heavy mineral sands

Industrial uses of zircon. Zircon ($ZrSiO_4$) is obtained as a coproduct during the separation and recovery of the titanium minerals. Zirconium oxide offers high light reflectivity and thermal stability and, thus, is used mostly in refractory products, as an opacifier for glazes on ceramics (such as tiles), and by the foundry industry (Bedinger, 2013b). Zircon is used as an abrasive. It is an additive to metal alloys, chemicals, pharmaceuticals and medicine and food; and it is used in welding rod coatings, cosmetics, glass faceplates for television tubes, computer disc drives, lightweight warm and protective clothing, ballpoint pens and wear-resistant knives.

In 2015, the dominant end-use market for zircon was the ceramics industry, which accounted for about 50 percent of the total zircon market (Bedinger, 2016b, 2016c). Other markets, in decreasing order, were zirconia (ZrO_2) and other zirconium chemicals, refractory and foundry applications.

Global production of zirconium. Global mine production of zirconium mineral concentrates was estimated to be about 1.42 Mt (1.56 million st) in 2014, an increase of 37 percent from global zirconium production of 1.04 Mt (1.14 million st) in 2000 (Hedrick, 2002; Bedinger, 2016c). In 2014, the leading zirconium concentrate producing countries were Australia and South Africa (Table 1) with 39 percent and 27 percent of global production, respectively (Bedinger, 2016c). Production was consistent with demand as the three largest global producers of zircon — Iluka Resources Ltd. of Australia, Rio Tinto of the United Kingdom and Tronox Ltd. of Stamford, CT, USA — reported stable market conditions (Bedinger, 2016b).

In February 2016, Iluka announced that it would suspend mining and mineral processing at its Jacinth-Ambrosia Mine in South Australia for 18 to 24 months, beginning in April, in order to draw down existing inventory. MZI Resources Ltd. of Australia completed construction of its Keysbrook Project in Western Australia and produced its first zircon product in November 2015. Other heavy mineral exploration and mining projects with significant zircon resources were underway in Australia, Brazil, Kenya, Madagascar, Mozambique, Senegal and Sri Lanka.

Iluka, the largest global producer of zircon concentrates, was expecting zircon production and sales in 2016 to exceed those of 2015. TZ Minerals International Pty. Ltd. projected an increase in global production in 2016 as new sources in Africa were being developed.

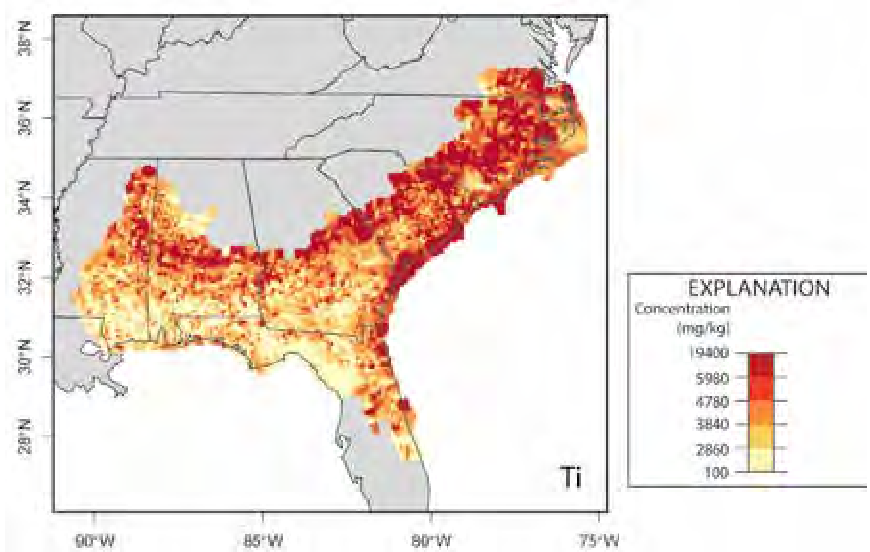
Industrial uses and production of monazite from heavy mineral sands

Until the mid-1960s, monazite extracted from HMS deposits was the primary global source for rare earth elements, with most of this monazite production from Brazil and India. In 1965, when full-scale mining and production of rare earth elements began from the Mountain Pass carbonatite deposit in California, the role of HMS deposits as sources of rare earth elements from monazite in placer deposits was greatly reduced.

Some countries, such as China and India, have ambitious programs in nuclear power. The countries have limited resources of uranium

Figure 6

Map of the southeastern United States showing the distribution of titanium in stream sediment samples. From Ellefsen and others (2015).



and considerably larger resources of thorium. India's sizable resources of thorium, possibly the largest in situ thorium resources in the world (NEA-IAEA, 2014), are in the form of monazite [(Ce,La,Nd,Th)PO_4] in HMS along their eastern and western coastlines. Government-supported projects, in particular in India and China, as well as France, Norway, Canada, Brazil and Russia, have recently devoted research toward the development of thorium-based nuclear power (NEA-IAEA, 2014; NEA-IAEA, 2015; Van Gosen and Tulsidas, 2016).

Monazite concentrate production, as a coproduct of HMS mining for titanium minerals and zircon, has occurred in recent years in India, Malaysia, Thailand, Vietnam and Brazil, in decreasing order of production (Van Gosen and others, 2014). Indian beach placers are the principal present-day source for the production of monazite, mainly obtained from coastal shores in the states of Kerala and Orissa. The monazite is stockpiled to provide source material for future development of thorium-based nuclear power, under a program sponsored by the Department of Atomic Energy of the Indian government (Anantharaman and others, 2008). The typical composition of monazite from the Kerala deposits in India is reportedly 57.5 percent REE oxide and 7.96 percent thorium oxide (ThO_2) (Kerala Minerals & Metals Ltd., 2016). Monazite is currently processed as a stockpile of thorium hydroxide by the Rare Earths Division of Indian Rare Earths Limited (Indian Rare Earths Limited, 2016).

In recent years in the United States, while studies show that monazite can comprise up to 12 percent of the heavy mineral suite (Bern and others, 2016), monazite has not been stockpiled due to concerns about the radiation from thorium within the monazite. Instead, monazite recovered during the gravitational separation of the heavy minerals is typically blended with the waste sands and silts and returned to the pit during remediation, thereby returning the monazite to the ground at proportions similar to the original HMS.

U.S. production and resources of heavy mineral sands

Recent U.S. production. In May 2015, Southern Ionics Inc. completed construction of its mineral sands processing plant near Offerman, GA, to process heavy mineral concentrates from its mining operation in Charlton County. In February 2016, Southern Ionics announced a curtailment of operations owing to a decreased demand for titanium concentrates that was anticipated to extend through most of 2016 (Bedinger, 2016a).

In May 2015, Southern Pines LLC began to build a wet concentrator plant to process existing tailings deposits in New Jersey to produce a zircon-ilmenite concentrate. Completion of the plant was expected in 2016.

Iluka Resources Ltd. concluded operations at its Brink and Concord Mines near Stony Creek, VA, at the end of 2015 (Bedinger, 2016a; Iluka Resources Ltd., 2016). Iluka commenced mining of HMS in this area of southeastern Virginia (Dinwiddie County) in 1998 (at the Old Hickory deposit). Using openpit, dry mining techniques the company has worked unconsolidated, Tertiary-age HMS deposits in this area to recover ilmenite, rutile and zircon (Iluka Resources Ltd, 2013; Van Gosen and others, 2014; Berquist and others, 2015).

Mining and processing of HMS for titanium minerals and zircon continues at The Chemours Co. operations along the Pleistocene-age Trail Ridge deposits, east of Starke, FL. DuPont began mining on the southern end of the Trail Ridge in 1949. Recent operations continue to mine HMS along the trend of Trail Ridge, which now includes mines in Baker, Bradford, Clay and Duval counties.

U.S. heavy mineral sands resources. The coastal plain of the southeastern United States has substantial resource potential for HMS deposits. Clastic sediments have been deposited along the Atlantic Coastal Plain (Fig. 5) from the Late Cretaceous to the present. The sedimentary units are weakly consolidated and locally enriched in heavy minerals, making them candidates for economic deposits of HMS. As a result, large expanses of the Coastal Plain of the southeastern U.S. are permissive for extensive, potentially economic deposits of heavy minerals (Neiheisel, 1962; Carpenter and Carpenter, 1991; Grosz and others, 1992; Grosz, 1993; Grosz and Schruben, 1994; Van Gosen and others, 2014). These deposits are known to include ilmenite, rutile, zircon, and locally minor amounts of monazite and xenotime.

Berquist (1987) was the first to recognize and report heavy-mineral-rich sand deposits in southern Virginia. His report prompted exploration for this deposit type in southeastern Virginia, leading to the discovery of the Old Hickory deposits, which were subsequently mined by Iluka Resources. The heavy mineral deposits of this belt initially developed in the upper Coastal Plain, just east of the "Fall Line" (Fig. 5) — a regional term used to describe the contact zone between the basement rocks of the Piedmont region on the west and much younger sediments of the Coastal Plain on the east. HMS in the western parts of the Coastal Plain of Virginia and North Carolina, along the Fall Line, are interpreted to be Pliocene sedimentary deposits that formed during worldwide transgression-regression events, which occurred between 3 and 3.5 million years ago (Ma) (Carpenter and Carpenter, 1991). On the basis of heavy-mineral estimates for 19 deposits within this belt, Carpenter and Carpenter (1991) calculated a total regional resource of 22.7 Mt (25 million st) of heavy minerals in 377.8 Mt (416 million st) of sand, with an average heavy-mineral content of 6 percent. Average mineral distribution within the heavy mineral suite was estimated to be 60 percent ilmenite, 2.5 percent rutile, 12.5 percent zircon, 8.5 percent staurolite, 0.7 percent tourmaline, 3 percent kyanite, 1.3 percent sillimanite and 11.5 percent other heavy minerals (mostly limonite) (Carpenter and Carpenter, 1991).

In addition to Tertiary and Late Cretaceous HMS deposits along the Fall Line, north-south-trending ridges of HMS cross northeastern Florida and southeastern Georgia. An example is the Pleistocene-age Trail Ridge mined by Chemours, east of Starke, FL, located about 65 km (40 miles) inland from the current shoreline. Other Pleistocene and Pliocene ridges of HMS in northeastern Florida lie closer to the coast, such as the Duval Upland ridge deposit at Green Cove Springs, FL, which contains an average of 3 percent heavy minerals that included ilmenite, leucoxene, rutile, zircon and monazite (Staatz and others, 1980). The Green Cove Springs deposit was mined from 1972 to 1978 by Titanium Enterprises, then later by Iluka Resources until 2005. Historical accounts of the early HMS operations in Florida are detailed in Staatz and others (1980), and summarized in Van Gosen and others (2014).

The Atlantic Coastal Plain extends to New Jersey on its north terminus (Fig. 5). HMS deposits of Neogene age have been mined in the area of Lakehurst, NJ, where two companies produced mainly an altered ilmenite (Van Gosen and others, 2014). The deposit's highest-grade intervals are about 5 m (16 ft) thick and contain 5 to 25 percent heavy minerals (Puffer and Cousminer, 1982; Force, 1991), formed in the swash zone along the Neogene shore (Carter, 1978; Puffer and Cousminer, 1982).

On the western part of the ancient Atlantic Coastal Plain, HMS deposits occur in Late Cretaceous sedimentary layers near Bruceton, TN. The McNairy Sand, about 50- to 100-m (164- to 328-ft) thick, is the shoreline facies of a Late Cretaceous transgressive-regressive sequence in the Mississippi embayment (Fig. 5), which extends from Mississippi to southern Illinois (Force, 1991). The basal member of the McNairy Sand, which is as much as 15-m (50-ft) thick, contains concentrations of heavy minerals, which are locally as high as 17 percent (Wilcox, 1971). The heavy mineral suite averages 55 percent ilmenite, 8 percent leucoxene, 2 percent rutile, 10 percent zircon and 1 percent monazite (Force, 1991); staurolite, kyanite, and tourmaline are also present (Wilcox, 1971).

U.S. Geological Survey study of heavy mineral sands of the Atlantic Coastal Plain

A U.S. Geological Survey (USGS) project, scheduled to continue into 2018, is evaluating the coastal plain of the southeastern United States for critical and strategic commodities — particularly titanium and zirconium — that are potentially recoverable from the large, undeveloped deposits of heavy mineral sands in this vast region. This project is a continuation of a recent USGS study that focused on rare earth elements resources in the Atlantic Coastal Plain (Shah and others, 2015). The current project has two basic assessment objectives: determine the regional extent of this resource endowment and evaluate the factors that affect the development of mines for heavy mineral sands.

To address the study's first objective, the project has focused on the spatial distribution of known and potential HMS deposits and the associated geologic processes. This involves mapping the probabilities for high concentrations of heavy mineral sands. The maps generated identify favorable areas where industry might conduct exploration and development. Understanding the processes that formed these deposits will aid in interpreting both the spatial distributions maps and the probability of occurrence maps. To be comprehensive, the study will use multiple, existing earth-science data sets, such as geochemical, geological, geophysical, hydrological and geographical data. Initial analyses of these different data sets were conducted by Ellefsen and others (2015), Shah and others (2015), and Bern and others (2016), which have established the foundation for this investigation. For example, one data set is the geochemical analyses of stream sediments from the National Geochemical Survey (Smith, 1997). Within the study area, there are approximately 5,200 sediment samples, each with chemical analyses for titanium (Fig. 6) and zirconium; these elements serve as proxies for the heavy minerals of high value. Another data set is airborne radiometric data that were collected as part of the National Uranium Resource Evaluation program (Hill and others, 2009). In the study area, there are approximately 1.6×106 measurements of equivalent thorium concentrations, which indicate accumulations of monazite and xenotime, and hence HMS.

To address the second overall objective of the study, the project is conducting a mineral industry analysis and material flow study of HMS deposits, from mine to market. Activities involve:

- Compare the character of undeveloped U.S. deposits to analogous explored deposits and active operations in other parts of the world. This comparison will place into context the economic potential of the U.S. deposits as a potential domestic supply source.
- Examine the estimated lead time requirements for development.
- Examine the potential influence on reduction of import reliance.
- Develop flow figures that display the concept of mine to market and include byproducts, coproducts, and waste products of this deposit type.
- Illustrate the mining and mineral processing requirements, waste generation, resource requirements, and infrastructure requirements. These requirements include land, grade, tonnage, water, energy, site operations, fuel, and other factors.
- Examine the associated environmental factors and social issues affected by competing values that may restrict development. The competing values involve land disturbance, urban development, recreational values, national forest, national seashores, water quality and quantity, radiation issues associated with the sale, stockpiling, and reburial of thorium-bearing monazite and xenotime.

Outlook

HMS deposits will continue to serve as the major source of titanium, zirconium and a few other industrial minerals because these deposits have several advantages:

1. The deposits are usually voluminous, covering large areas.
2. Deposits are usually located at the surface or at shallow depths beneath thin layers of sediments.
3. Individual mined deposits typically comprise >10 Mt (11 million st) of ore (the total size of the individual sand-silt body) often containing >2 or 3 percent heavy mineral content.
4. They are generally easy to excavate. Most HMS deposits mined today vary in coherence from unconsolidated to poorly consolidated; thus, they are generally easily excavated and worked with heavy equipment).
5. Well-established, highly mechanized, and efficient mineral-separation techniques are used in modern heavy-mineral processing plants.
6. Modern plants can control a continuous feed of high volumes of ore materials that thereby maintains an effective pace of mineral separation, which can produce high-purity mineral products within hours.
7. HMS deposits supply several salable minerals as coproducts to the titanium minerals (such as zircon, staurolite, garnets, and (or) monazite).

For these reasons, and because HMS deposits are the major sources of titanium and zirconium in particular, the mining and processing of HMS deposits should remain an important sector of the industrial minerals industry in the future. (References are available from the authors.) ■

Building and executing an effective risk system for the mining industry

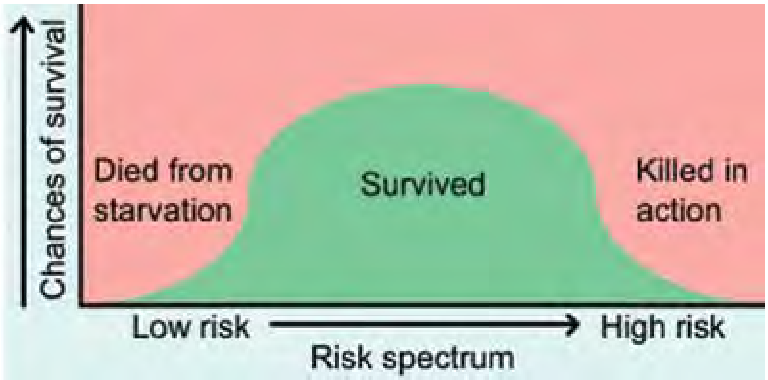
by Ewan Alexander

As human beings, we have managed risk since the dawn of the ages and have been adept at doing so. In order to survive, we hunted or gathered. If we did not take enough risk, we died. If we took much risk, we died (Fig. 1). As individuals and tribes, risk had to be optimized to maximize our chances to thrive, as individuals and as tribes.

In today's world, the risks are vastly different, but in order to thrive, these must be managed. And no industry knows this as much as mining. In fact, the International Council of Mining & Metals (ICMM) has proposed the Critical Risk Model (Fig. 2) as a means of identifying critical risk, critical controls and associated performance standards. The ICMM focuses on sustainable development performance in the mining and metals industry. It has 23 members, representing some of the largest mining companies in the world.

Figure 1

Risk spectrum. Source: Human Behaviors in Hazardous Situations. Jan M T Dallmans.



This approach is going to help the mining industry. But it must be applied effectively, with the acknowledgment that the system alone cannot be effective. We can say this confidently, as even companies known for the strength of their risk and safety management systems continue to experience significant incidents, and, in some cases, catastrophes. Why does that happen when all safety metrics, including injury rate, are pointing in the right direction?

In the view of the author, it is only when leadership, culture and systems work in complete harmony that the resilience of an organization to manage its significant risk is at an optimal level. It remains an ongoing leadership challenge to maintain that balance and the optimal mindset in the organization. So how do you maintain that special balance?

Let's start with a basic premise. Leadership, supported by simple effective systems, creates culture which creates outcomes. Everyone going home safely is an outcome, as is cost effective operations, and to achieve those outcomes efficiently, the organization must focus on the inputs. And those inputs include effective leadership, effective systems (for the purposes of this article, risk and health, safety and environment (HSE) systems), good planning, stable operations and competent workers. This article will focus on gaining maximum performance from your risk management system.

In order to become risk competent, a company must have a risk management system. These systems range from great complexity to elegant simplicity. The level of detail is determined by the hazards being managed, and there is tremendous skill in determining the optimum level of detail to manage the associated risks. Too much detail and the system becomes unmanageable and caves in under its own weight. Too little and its controls cannot mitigate or prevent all possible causes. It is a delicate and precarious balance.

An effective system is one that creates critical controls, measured against objective performance standards, and this will help the mining industry in the following ways:

- It will focus leadership on managing those risks that are material to the business and its employees. Material in this usage, means "critical to business health and employee well being."
- Supervisors will focus on critical controls. These controls are the barriers between a hazard and the risk that the hazard becomes a reality (incident). As an example, the first thing that a supervisor will focus on when going out in the field is whether the controls protecting their employees are effective.
- Employees will know the controls that are protecting them and what it takes for them to be effective. They will be risk competent. They will know what

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conditions must exist for the controls to work, and will challenge control effectiveness as part of a continuous improvement cycle. They will follow procedure and know when it is not safe to follow procedure.

- These controls will be tested regularly against objective performance standards. Objective, in this case, specifically means that it requires a yes or no to answer. There either is, or is not, an engineered anchor point for employees to tie off when working at heights. There is no opinion involved, it either does or does not exist. The harness either has or has not been inspected by a competent individual within the prescribed review period.
- There will be a management of change process that will allow thinking individuals to effectively manage the risk associated with the changed hazards.

A risk competent organization also knows the limits of its system in terms of what it can and cannot do. It will be aware of the "blind spots" created by the system. These blind spots emerge for a number of reasons, the most significant being as follows.

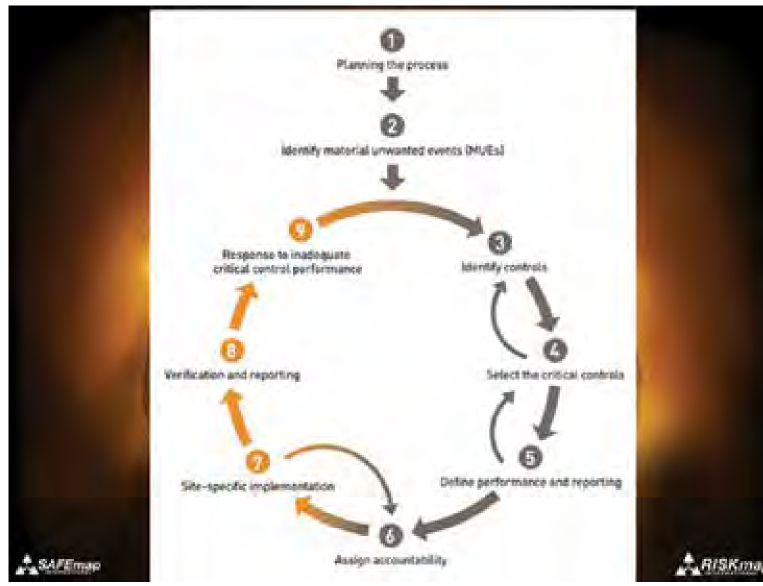
Overly simple or overly complex. The organization must be clear on how it aggregates its risks. When managing hazardous atmosphere underground, the cause of a hazard could range from noxious vapors, equipment exhaust to fire and explosion. The critical controls are similar between all of these hazards, but not the same. Ventilation is common, vehicle maintenance impacts noxious vapors and possibly vehicle fire. It is a delicate balance learned from experience.

Inadequate risk identification. Hazards exist in terms of how work is done. So hazard identification must evolve from work planning and standard operation. Too often, the hazard is generally identified but too broadly defined, resulting in controls that are overly conceptual and don't relate to the way that workers need to complete their work. As an example, hydrocarbons are identified as a potential for explosion, but the risks of storage, versus loading or unloading are completely different. The hazardous analysis/risk assessment needs to focus on the individual steps of loading, storing and unloading. The controls are likely to be different in each case.

Operation instability. Stable, well-planned operations and construction that are consistent are far more effective and easier to control. Sources of instability in the process should be the focal points for management. Make the process stable, and controls are more likely to be effective. If employees are required to manage around instability, they will start to improvise, which will either defeat or undermine the controls that management thinks are in place. Workers can be counted on to manage risk, but make it easier for them so that they can focus on the low-probability, high-consequence events.

Figure 2

ICMM model for Critical Risk Management.



Everything in the green. Critical controls are all working, and a desire to report to management that all controls are effective results in complacency. An organization must continually be able to challenge how well the controls are working for them and how they might be vulnerable to random events. Inclusion of randomness is a key skill. The manager of the Piper Alpha rig, which blew up in the North Sea in 1988, testified that "I knew everything was okay, because I never got a report that anything was wrong."

Risk migration. Because one risk is controlled effectively, a new risk can be created. For example, an openpit mine banned passing of haul trucks when a fatality occurred. This caused light vehicles to race ahead of the haul trucks, eventually resulting in a collision and fatality.

Risk homeostasis. This is a known human behavior. Once a person feels safe, he or she will take more risk. Further, as risks are successfully

Safety

Figure 3

The SAFEmap maturity scale.

managed, over time this consistency results in overconfidence. It can also result in people paying less attention to the critical controls, no continuous improvement cycle and redundancy-induced overconfidence, as occurred within NASA in the fateful Challenger launch.

Failure to take advantage of learning from significant incidents. This can occur when:

- The mine is focused primarily on U.S. Mine Safety and Health Administration (MSHA) recordable injuries and injury rate and does not adequately pay attention to actual or potential events where someone might be killed.
- The company fails to adequately investigate and learn from significant events.
- The organization simply fails to update and test critical controls based on the experience gained from an incident or does not apply the learning to sister sites.

A strong inclination to blame the worker for events that occur. When investigations blame the worker more than 10 percent of the time, then systemic causes and remedies are missed.

To enable companies to benchmark themselves, RISKmap, a division of SAFEmap, has developed a progression system that measures the organization's maturity in terms of leadership, systems and safety culture.

The safety culture model was developed 16 years ago for an Australian mining industry study and has since been applied at more than 250 sites worldwide with participation of approximately 300,000 employees.

Organizations without risk systems start at a reactive level of maturity, and its people rely totally on their own instinct to survive. Organizations can progress to become resilient in their capability to execute their business effectively in a way that cares for their people.

Organizations benchmarked to date live in the reluctant to reliable continuum. And the most important aspect is that those that have completed the benchmark gain feedback, which can drive improvements in their leadership, systems and culture in a way that assures that all three pillars can work together.

The benchmarking process is fairly simple. Data is gathered from electronic surveys, focus groups involving less than 10 percent of the population and a risk deep dive involving two to three-day site visits. Companies then get feedback based on benchmarked performance similar to the three charts in Fig. 4, strengths, weaknesses, opportunities and threats (SWOT) analysis and specific recommendations.

This approach was used most recently with a large South American mining company. The feedback provided to the board was considered extremely effective. The SWOT approach, broadly provided the following feedback. (Note that these are generalized for the purposes of this article.)

For example, the organization had done

Figure 4

An example of the benchmarking process.

an outstanding job of identifying controls where incidents had occurred but limited their effectiveness:

- Failure to delgegate control ownership far enough in to the organization resulted in superintendents owning more than 20 controls. The organization was eager to be more involved, and the superintendent was overloaded, creating the possibility of inadequate control effectiveness reviews).
- A focus solely on past events meant that other 'new' risks (for example, probable natural disasters, or loss of control of vehicles, were not included in the analysis and subsequent focus of the risk system).
- Effective integration of planning with risk controls was done extremely effectively in the pit. The leadership assured and convinced their employees that speeding in the pit was not necessary to achieve the production plan, and until doing so, employees continually defeated the critical control of haul road speed. Until convinced, employees believed that speeding was necessary for them to achieve their bonus and that desire would always trump the critical control process. Integration of planning, with speed control, with production

Table 1

Strengths, weaknesses, opportunities and threats (SWOT) chart.

Strengths. The business had effectively and consistently executed their risk system (in this case it was the ICMM Critical Risk Management (CRM) model).	**Weakness** Risk system as applied was overly complex creating a significant and costly operational burden to the company.
Opportunities. • Significantly simplify the controls and measure against objective performance standards. • Harness the tremendous enthusiasm in the organization to progress to the next level of capability.	**Threats** • Some elements of leadership were not aligned with the program. • Narrow and prescribed risk focus left material risks outside of scope.

bonus, resolved the issue. However, in a different situation, a change in the execution of the mine plan resulted in migration of vehicle interaction in to a very tight area of the mine, significantly increasing the risk of fatality due to vehicle collision. In this case, the change to the plan caused a risk migration that went unmitigated, albeit on a temporary basis. The problem, once recognized, was easily resolved by staging vehicles into the area.

Principles of effective risk management system design.

The following five beliefs and associated principles were developed by RISKmap. They form the basis of effective system design. When organizations align their system accordingly, they do make progress up the risk continuum. The ability of the company to live by these principles is completely measurable and can be benchmarked.

1. Acceptance that risk always exists and cannot be reduced to zero and therefore, hazards must be recognized and controlled.
2. Leadership, supported by effective systems, creates the culture, which creates performance. Safe performance is an outcome, as is quality, compliance and productivity.
3. Risk can be proactively identified, eliminated or effectively managed through the design of controls.
4. Competence of teams and individuals to understand, perceive, judge and mitigate risk is the basis of high performance.
5. When the plan must change, then change the plan.

Mining has traditionally been a dangerous occupation. In today's world, we can no longer accept that a person should be killed in his or her chosen occupation. We collectively have the desire and knowledge for leadership to create the systems and culture that will enable organizations to become risk competent. And a benchmarked process that measures the right competencies can help all in that journey. ■

MSHA issues safety call to coal mines;

Inspectors will conduct "walk and talk" visits at mines

SINCE OCTOBER 2015, eight fatalities and more than 1,100 nonfatal accidents have occurred in the nation's coal mines, resulting in restricted duty, missed days at work and permanent disabilities for the miners who worked there. While injury rates have been fairly consistent during this time period, records indicate a trend in accidents resulting in more serious injuries. The circumstances in at least 30 of the accidents might have led to fatalities.

In response, the U.S. Mine Safety and Health Administration is issuing a call to safety to coal miners working in underground and surface mines around the country. Inspectors engaged coal miners and mine operators in "walk and talks" through Sept. 30, reminding them to stop and take a breath before proceeding with the next task at hand.

The most common outcomes of the more than 1,100 mining accidents — 250 of which occurred at surface operations — were injuries to the back, shoulders, knees and fingers. In the near-fatal accidents, the majority were attributed to powered haulage, electrical and machinery classifications.

The majority of nonfatal accidents occurred in West Virginia, with 419; Kentucky, with 191, and Pennsylvania, 130.

"These walk and talks were intended to increase miners' awareness of recent accidents, encourage the application of safety training and raise hazard recognition," said Joseph A. Main, assistant secretary of labor for mine safety and health.

Since October 2015, more than 1,100 nonfatal accidents occurred in the nation's coal mines, according to MSHA data.

The number of nonfatal accidents by state is as follows:

Alaska 1; Alabama 42; Arizona 7; Colorado 9; Illinois 94; Indiana 46; Kentucky 191; Louisiana 2; Maryland 7; Montana 5; North Dakota 4; New Mexico 20; Ohio 31; Oklahoma 4; Pennsylvania 130; Tennessee 2; Texas 15; Utah 16; Virginia 42; West Virginia 419; Wyoming 37. Total, 1,124. ■

Fragmentation modeling
using the Multiple Blasthole Fragmentation (MBF) model at an openpit mine

by R. Yang, C. McAllister, J. Berendzen and D. Preece

Abstract ■ The Multiple Blasthole Fragmentation (MBF) model models multiple explosive charge contributions and the effect on fragmentation of delay timing with its associated scatter for each blasthole. The model uses near-field blast vibration attenuation parameters and the ground p-wave velocity as inputs for part of the in situ rock property to model rock fragmentation. It models most blast design parameters explicitly and simulates the effect of wave reinforcement due to the interaction of simultaneously arriving waves or diminishing cooperative contribution from long delay intervals between charges within a blasthole or among blastholes. The fragmentation size is calculated at three-dimensional grid points within a blast, and the fines and oversized blocks are treated explicitly. The model takes a surveyed irregular geometry of the free face of a blast as the calculation boundary.

This paper presents a case study on applying the MBF model at an openpit mine. Near-field vibration measurements from signature hole blasts were conducted to obtain the stress-wave magnitude and attenuation parameters as well as ground sonic velocity. A production blast was then monitored with the corresponding fragmentation measured, serving as site-specific inputs to the MBF model. Various blast design scenarios were then simulated to develop ones that provide better fragmentation to improve mill throughput for the mine.

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Introduction

The semiempirical fragmentation models currently found in the literature (Cunningham, 1987; Lownds, 1995) cannot explicitly model contributions from multiple blastholes with varying delay intervals. Most of these models are not three-dimensional. Furthermore, these models predict an average fragmentation size within a volume surrounding a blasthole and use the average size to generate a size distribution over the volume. The percentage of fines and oversize blocks is included in the distribution. Typically, such models are inadequate for predicting fines and oversize blocks (Cunningham, 1987).

R. Yang and D. Preece, members SME, are principal research fellow and global technology manager of blast modelling development and support for the Americas, respectively, at Orica USA Inc., C. McAllister is mine engineer/ blasting supervisor at Simplot Phosphates LLC and J. Berendzen is technical service engineer at Southwest Energy Inc. **Paper number TP-15-053. Original manuscript submitted November 2015. Revised manuscript accepted for publication May 2016. Discussion of this peer-reviewed and approved paper is invited and must be submitted to SME Publications by Jan. 31, 2017.**

The Multiple Blasthole Fragmentation (MBF) model, whose concepts and site-specific applications are presented in Yang (2014, 2015a and 2015b), models rock fragmentation mechanisms and size distributions based on the work of Seaman, Curran and Shockey (1976) and calculates peak particle velocities (PPVs) according to Yang and Scovira (2008). Included are: (1) the nonlinear charge weight superposition, (2) the effect of waveform broadening using a variable width time window for each explosive charge, (3) the delay time of each charge and (4) broken ground screening, which accounts for blasthole confinement and interaction. The fragmentation distribution is calculated at up to several millions of three-dimensional grid points within a blast. A grid point in a detached rock mass due to fragmentation by earlier firing holes ceases to receive energy from later firing blastholes. Fines and oversized blocks are treated explicitly.

The model accepts inputs from blast design parameters, such as: (1) location and orientation of each blasthole, (2) stemming length, (3) blasthole diameter, (4) multiple decking, (5) bench height, (6) initiation points in a blasthole and initiation sequence within a blast pattern and (6) explosive strength. It models the effect on fragmentation of delay timing with its associated scatter for each blasthole. The model also has statistical modeling capabilities for geological random variation of the attenuation of particle velocities, ground sonic velocity scattering, and timing scatter of blasthole delays (Yang and Lownds, 2011).

PPV calculation. Persson, Holmberg and Lee (1994) used integration of the linear superposition of PPVs from charge increments along a charge length to calculate the PPV in the vicinity of a blasthole. Such linear superposition may be suitable if the material response is close to linear elastic. However, in most cases, in the vicinity of blastholes, rock behavior is significantly nonlinear.

For the MBF model, the effective charge weight from a single charge to a point of interest is calculated by integration of nonlinear charge weight superposition along the charge length. The PPV at a calculation grid point is based on nonlinear charge weight superposition from different contributing charges accounting for the delay timing between them, the same approach as described in Yang and Scovira (2008). A few concepts are described below.

Nonlinear charge weight superposition. Figure 1 shows a point of interest A — a calculation grid point — and an explosive charge demonstrating how the effective charge weight is calculated using nonlinear charge weight superposition.

The charge weight of the segment Δl is:

$$\Delta w_i = \Delta l \cdot \rho \cdot \frac{\pi d^2}{4} \tag{1}$$

where d is the charge diameter and ρ is the density of the explosive. The effective charge weight, Δw_e, at the point A from the segment Δl is defined as the charge weight that generates the same PPV contribution as the segment Δl but is at the nearest distance, d_n, from the charge to the point of interest A:

$$\alpha \cdot (d_n)^{-\beta} (\Delta w_e)^{\gamma} = \alpha \cdot (d_i)^{-\beta} (\Delta w_i)^{\gamma} \tag{2}$$

$$\Delta w_e = \Delta w_i \left(\frac{d_n}{d_i} \right)^{\frac{\beta}{\gamma}} \tag{3}$$

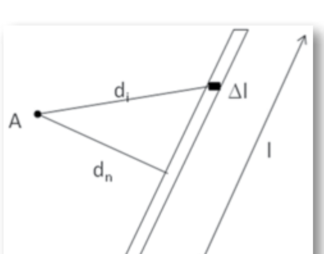
Consequently, the cumulative effective charge weight of the whole charge at point A is:

$$w_e = \int \Delta w_e = \int \Delta w_i \left(\frac{d_n}{d_i} \right)^{\frac{\beta}{\gamma}} = \frac{\pi \rho d^2}{4} \int_l \left(\frac{d_n}{d_i} \right)^{\frac{\beta}{\gamma}} dl \tag{4}$$

where d_n is the nearest distance in meters from the point of interest to the charge, and d is the function of the location of dl along the charge length in meters.

Figure 1

A point of interest A – a calculation grid point – and an explosive charge.



If a distance is defined, the charge-weight-scaled distance can be calculated with the effective charge weight using Eq. (4) and the scaling method above to scale the charge weight to the defined distance. The nearest distance from the point of interest to the dominant charge may be used, as for the charge weight scaling and the scaled distance calculation. The dominant charge is defined as that having the minimum scaled distance among all charges in the blast (Yang and Scovira, 2008).

If the stress wave from an explosive charge passes through broken ground created by earlier firing charges, the amplitude and frequency of the stress wave will attenuate more than when traveling the same distance through intact rock. This additional attenuation due to earlier firing charges is termed "broken ground screening" (Yang and Scovira, 2008) and is used to modify the resultant PPV. Also, earlier firing blastholes in the vicinity of a firing blasthole will reduce the confinement to the hole and consequently reduce the fragmentation potential (Yang and Kay, 2011).

For modeling rock fragmentation by multiple delayed blastholes, any model — even a full waveform superposition model — must account for the case that fragmented and detached rocks cannot receive further energy input from later firing blastholes. For example, the rocks that are fragmented and moved by blastholes in the first row may not get any further input from the blastholes in the second row if the delay between the rows is sufficiently long. Similarly, if a volume of rock is fragmented and displaced by an earlier firing blasthole or blastholes it will not receive any further energy from a later firing blasthole or blastholes if the delay time is sufficiently long.

The MBF model uses two concepts, described in Yang and Scovira (2008), to model this phenomenon and the intercharge timing delay effects: (1) a dominant charge at each grid point and (2) a variable time window for each charge.

Fragmentation at a point of interest. Seaman, Curran and Shockey (1976) developed a computational model of fracture and fragmentation for ductile and brittle materials based on projectile impact experiments and theoretical analysis. The model favorably compares fragment size distributions with measurements and thus appears to be highly relevant and fundamental research work for rock blast fragmentation modeling. Aspects of Seaman's theories on fragment size distribution and crack nucleation are adopted as the basis for the MBF model.

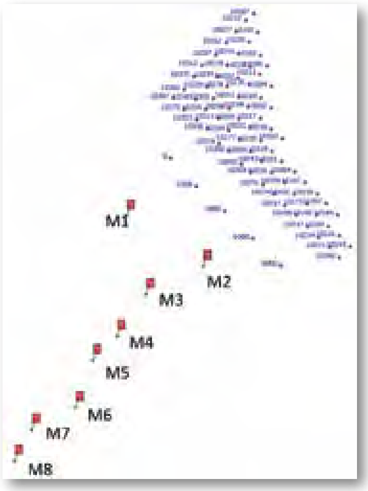
PPV induced from detonation of explosive charges was shown in Yang (2014, 2015a and 2015b) to be proportional to pressure or strain and stress. Based on Seaman, Curran and Shockey (1976), it is assumed that the number of fractures that produce rock fragments during blasting is governed by:

$$N = N_0 \exp\left(\frac{PPV - PPV_0}{\eta} \right) \tag{5}$$

where N_0 and η are rock property constants, PPV is the peak particle velocity in meters per second at the calculation grid point and PPV_0 is the threshold PPV for crack nucleation. The average fragment size is inversely related to the number of fractures:

Figure 2

Five signature holes and a production blast were monitored with eight vibration monitors.



$$\bar{x} = \frac{x_0}{N_0 \exp\left(\frac{PPV - PPV_0}{\eta}\right)} \quad (6)$$

where x_0 is the initial fragment size in meters. It may be the in situ block size due to joints.

The rock fragmentation distribution derived by Seaman, Curran and Shockey is that the cumulative volumetric fraction for fragment sizes smaller than x has the distribution:

$$R(x) = 1 - \exp(-x / x_c) \quad (7)$$

where x_c is the critical size of the size distribution in meters, in direct proportion to the average size of the distribution.

Size distribution of a blasted volume. The average fragment size or any percentage passing size can be displayed as a volumetric plot, that is, the size can be shown as a function of the location within the blast. The results can be displayed using various contour maps in a cross section cutting through the blast. A fragmentation size distribution can also be calculated over a given volume of the blast using:

$$R(x) = \frac{1}{n}\sum_{i=1}^{n}(1 - e^{-\frac{x}{x_i}}) \quad (8)$$

where n is the number of grid points in the blast volume assuming that the size of the grid mesh is constant over the volume, x_i is the average size in meters at the i^{th} grid point calculated from Eq. (6), and x is the passing size in meters. The passing percentage of a particular size can be calculated from Eq. (8).

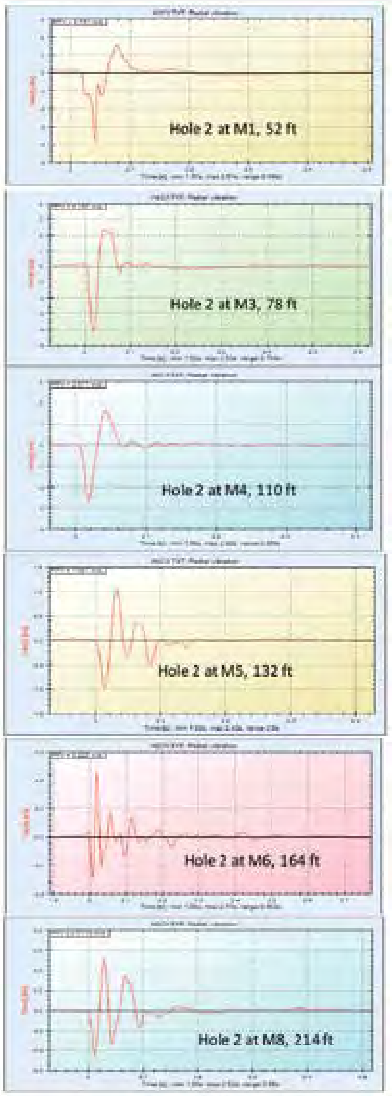
Case study: Phosphate mine

Five signature holes were blasted, with eight vibration monitors placed in different locations near the blastholes to record the blasts (Fig. 2). The distances between the blastholes and monitors ranged from 12 to 67 m (39 to 220 ft). The five signature holes were connected with long, two-second interval delays. Two seconds after the last signature blasthole fired, the production blast shown in Fig. 2 was initiated. The ground p-wave velocity was measured from the signature-hole blast. The information from the blast vibrations of the signature-hole blast was used as input to the MBF model, while the rock fragmentation measurement from the production blast was used to compare with the MBF modeling results and analyze the validity of the MBF prediction.

In each seismic monitor, three channels recorded the blast vibration from the signature hole blast and the production blast, while the fourth channel recorded the detonation time of the first signature blasthole, which is used with the vibration of the blasthole to calculate the ground p-wave velocity. Forty sets of signature hole vibration waveforms and eight sets of production blast vibration waveforms were recorded. The p-wave velocities of the ground were obtained across different distances. The average of the p-wave velocities was determined to be 1,750 m/s (5,742 ft/s). It was found

Figure 3

Recorded waveforms at different distances from a signature blasthole.



that the ground p-wave velocity is low, which is consistent with a soft layer of formation of the ground from the bottom of the blast to the monitors mounted on the ground surface.

From Fig. 3, which shows recorded waveforms at different distances to a signature blasthole, it can be seen that the waveform changes with recording distances. The general trend is that the farther the recording distance, the longer the duration time — more spread in time — of the waveform and the more complex the waveform becomes. This demonstrates the necessity of using multiple seed waveforms to model the contribution from different blastholes to blast vibration or rock fragmentation at a point of interest.

Figure 4 shows the regression of the PPVs of signature hole blasts versus scaled distance. The parameters from the regression are used as part of the input to the MBF fragmentation model or to the Multiple Seed Waveform (MSW) blast vibration model (Yang, Patterson and Scovira, 2009), if blast vibrations are to be predicted. The top curve represents the 97.5 percent upper-bound limit line, which means that 97.5 percent of measurement data fall below the line. The bottom curve is the best fit to the measurement data, with 50 percent of data falling below it or above it. The parameters of the two regression curves are used for the Monte Carlo simulation of the PPV variation (Yang and Lownds, 2011).

Figure 4

Regression of the peak particle velocity of signature hole blast versus scaled distance (1 in./s = 25.4 mm/s, 1 ft/lb$^{0.5}$ = 0.4526 m/kg$^{0.5}$).

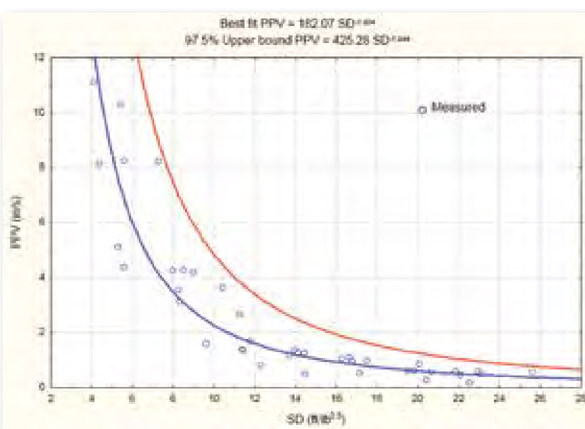


Figure 5

Rock fragments from the interior.

Rock fragmentation measurement

Rock fragmentation was measured using digital photographs. The cap rock and interior of the blast were measured separately. In each region, more than 20 pictures were taken at different time instances during the mucking to obtain the best representative rock fragmentation distribution. Some of the largest blocks were more than 1.5 m (5 ft) in diameter, mainly because the rock in the stemming region is much harder than the rock below the stemming region. Figure 5 shows the rock fragments under the cap rock or below the stemming region. The rock fragmentation from the interior rock is much smaller in size than the cap rock.

MBF modeling of the monitored blast

The MBF model uses the inputs from the signature hole blast vibrations to predict the fragmentation. Figure 6 shows the modeled average size of the rock fragmentation distribution within the blasted volume, and Figure 7 shows the model prediction agrees well with measured fragmentation, validating the model for the site.

Model predictions of design scenarios

After the model has been calibrated with the model parameters suitable to the site against the measurement of fragmentation, various design scenarios can be modeled to explore favorite design options for better mining economics, such as optimal fragmentation distribution to improve the mill throughput.

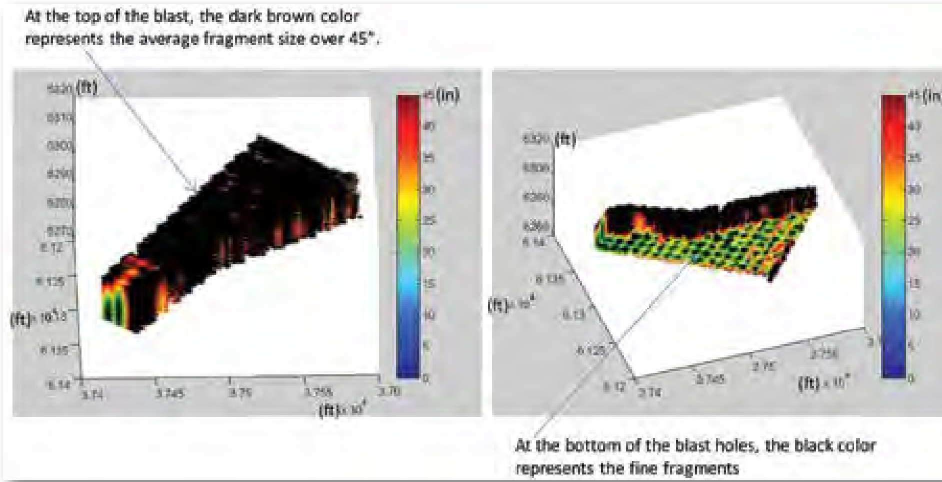
Figure 8 shows the result of modeling the original design but with the ANFO explosive mixture replaced with Orica's AmexLD 0.6, and with 1.2-m (4-ft) stemming instead of 2.4-m (8-ft) stemming, while maintaining the same bench height and blast pattern. It indicates that halving the stemming to 1.2 m (4 ft) and using AmexLD, which is low-energy ANFO, will improve the fragmentation. The scenario of ANFO with 2.4-m (8-ft) stemming generates more of the oversized blocks than that of AmexLD with 1.2-m (4-ft) stemming. The scenario of ANFO with reduced stemming of 1.2 m (4 ft) would generate the finest fragmentation shown in Fig. 8, but fly rock may be an issue due to the proximity of the mill.

Figure 9 shows a comparison of different delay timings of interhole and interrow, with 1 ms × 1 ms as the best and 17 ms × 25 ms as the worst, and 2 ms × 5 ms unable to provide significant improvement compared with 17 ms × 25 ms. These are consistent with stress-wave enhancement being more significant if the waveform reinforcement occurs when the two waves are both closer to the source without much attenuation. The 1 ms × 1 ms delay pattern may provide significant fragmentation improvement. However, the blast vibration and blast overpressure must be examined for specific site constraints.

Figure 10 shows a comparison of four different blast patterns and loading configurations on the fragmentation result, including the test production blast — test blast MBF

Figure 6

The modeled average size of the rock fragmentation distribution within the blasted volume.



and test blast measurement — from Fig. 7 for reference.

The 3.6 × 3.6 m (12 × 12 ft) pattern with pocket charges yields better fragmentation than the test production blast even though the former has substantially lower powder factor of 652 g/m³ (1.1 lb/yd³) than the latter's 890 g/m³ (1.5 lb/yd³). This could be attributed to the 3.6 × 3.6 m (12 × 12 ft) pattern with pocket charges providing better energy distribution in the stemming region than the 2.4 × 2.4 m (8 × 8 ft) test production blast. The 1.8 × 1.8 m (6 × 6 ft) pattern with satellite holes and longer stemming provides better fragmentation than the test production blast even though the former has slightly lower powder factor than the latter. Again, the former provides more uniform energy distribution but costs more for drilling and loading. Finally, the pattern of 2.4 × 2.4 m (8 × 8 ft) B × S with 11-cm (4.5-in.) hole and 1.2-m (4-ft) stemming results in the finest fragmentation among the four cases. This is due to its having the highest powder factor and more even energy distribution in the overburden among the four cases.

Discussion

The MBF model inputs the parameters of the near-field blast vibration attenuation and the p-wave velocity of the in situ rock mass to model the rock fragmentation from a blast design. The rock mass properties, such as strength, stiffness, density, joint spacing, filling materials between joints and joint frequency, are encoded in the p-wave velocity and vibration attenuation parameters. In addition, the parameters x_0, N_0, PPV_0 and η in Eq. (6) are rock properties for fragmentation by blasting. The values of these four parameters could be determined in reference to rock mass properties, such as rock strength, joint frequency, spacing and joint

Figure 7

Modeled rock fragmentation distribution for the whole blast compared with the measured fragmentation from the production blast.

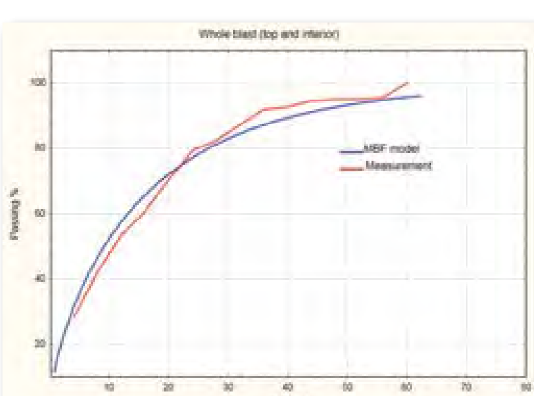


Figure 8

Modeled size distribution: AmexLD 0.6 with 4-ft stemming versus ANFO with 8-ft stemming.

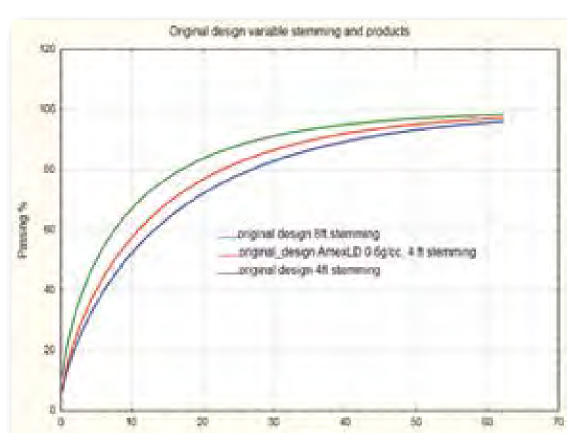


Figure 9

Comparison among different delay timings of interhole and interrow, showing the 1 ms × 1 ms.

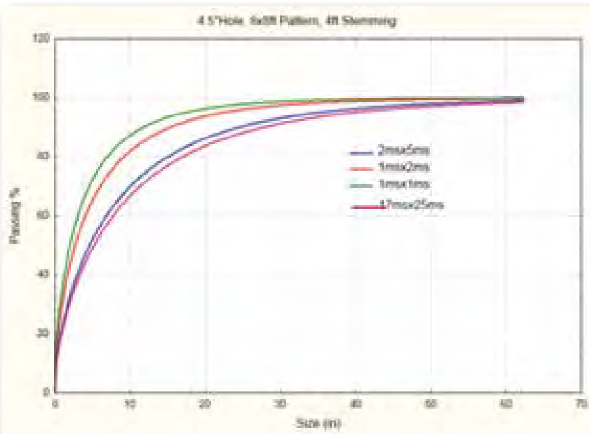
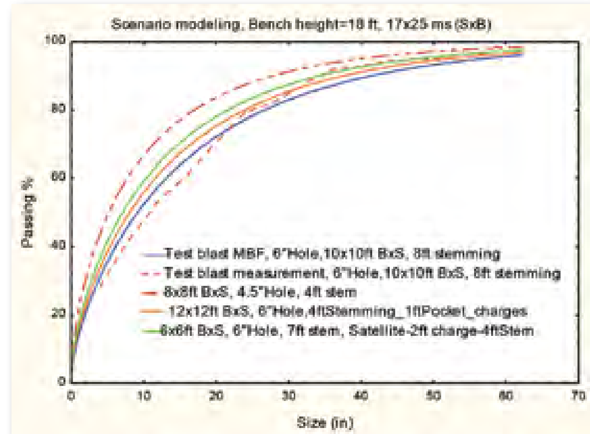


Figure 10

Comparisons of different blast patterns, blasthole diameters and stemming region charges.



properties. After determining the initial values from the rock mass properties, they are further adjusted during the model calibration with the rock fragmentation measurement from a test blast.

An average size is calculated at each grid point of calculation. A size distribution is assumed as described in Eq. (7). At grid points of calculation near a blasthole or in a region where shock waves collide, large PPV and small average size of fragmentation are calculated. With the assumed size distribution in Eq. (7), the fines of the fragmentation from blasting are assumed to be modeled by the MBF. The fines that are generated from material handing, such as digging and hauling, are not included in the MBF modeling.

It is recognized that the present fragmentation measurement by the image process could underestimate the fines from blasting. In Fig. 7, the discrepancy between the MBF prediction and the measured fragmentation could be due to underestimation of the fines by the image process. Although the image process of rock fragmentation has limitations, it remains the most widely used technique for rock fragmentation measurement because there is no other method that can provide better results and is also faster, more economical and accurate.

Conclusions

Near-field vibration measurements from signature hole blasts were conducted to obtain the stress-wave magnitude attenuation parameters as well as ground sonic velocities. This information along with the blast design parameters are inputs for the MBF model. By monitoring a production blast and measuring the corresponding fragmentation, the MBF model was tested for validation.

Various blast design scenarios were then simulated to develop one that provides better fragmentation so as to improve mill throughput for the mine. Parameters varied in this study included (1) blasthole diameter, (2) blast pattern, (3) strength and density of explosives, (4) pocket charges in the stemming region, (5) satellite holes, and (6) delay timing between blastholes.

By comparing the modeled scenarios, favorable blast designs were identified and implemented. The percentage of oversize material, defined as having particle size of 1.5 m (60 in.) or more, was 0.05 percent for the new design versus 4.3 percent for the original design. Productivity was improved to 18,000 tons of ore per shift, from 10,000 to 11,000 tons previously. Before the pattern adjustments, the mine would send 40 loads to the oversize fragment piles but now average about two loads per shot.

The case study indicates that the MBF model is useful as a tool for blast fragmentation optimization with the capability to model most blast design parameters explicitly. ■

References

Cunningham, C.V.B., 1987, "Fragmentation estimations and the Kuz Ram Model – four years on," 2nd *International Symposium on Rock Fragmentation by Blasting*, Society for Experimental Mechanics, Keystone, CO, pp. 475-487.

Lownds, C.M., 1995, "Prediction of Fragmentation Based on Distribution of Explosives Energy," Research Symposium of International Society of Explosives Engineers Meeting, Nashville, TN, February 1995.

Persson, P., Holmberg, R., and Lee, J., 1994, *Rock Blasting and Explosive Engineering*, CRC Press LLC, Boca Raton, FL, 560 p.

Seaman L., Curran D.R., and Shockey D.A., 1976, "Computational models for ductile and brittle fracture," *Journal of Applied Physics*, pp. 4814-4826, http://dx.doi.org/10.1063/1.322523.

Yang, R., 2014, "A 3D Multiple Blasthole Fragmentation (MBF) Model Based on Peak Particle Velocity, Nonlinear Charge Weight Scaling, Time Window of Contribution, and Dynamic Rock Fracture Models," Orica internal report.

Yang, R., 2015a, "A Multiple Blasthole Fragmentation (MBF) Model Based on Nonlinear Charge Scaling, Delay Time Contribution, and Rock Dynamic Fracture," 41st Annual Conference on Explosives & Blasting Technique, New Orleans, LA, ISEE.

Yang, R., 2015b, "A Multiple Blasthole Fragmentation (MBF) Model – Its Concept, Formulation, Capability, and Field Comparison Examples," 11th International Symposium on Rock Fragmentation by Blasting, Sydney, Australia, Aug. 24-30, 2015.

Yang, R., and Kay, D.B., 2011, "Multiple seed blast vibration modeling for tunnel blasting in urban environments," *Blasting and Fragmentation*, Vol. 5, No. 2, pp. 109-122.

Yang, R., and Lownds, M., 2011, "Modeling effect of delay scatter on peak particle velocity of blast vibration using a multiple seed waveform vibration model," *Blasting and Fragmentation*, Vol. 5, No. 1, pp. 31-46.

Yang, R., Patterson, N., and Scovira, D.S., 2009, "An Integrated Approach of Signature Hole Vibration Monitoring and Modeling for Quarry Vibration Control," 9th International Symposium on Rock Fragmentation by Blasting, Spain, Sept. 13-17, 2009.

Yang, R., and Scovira, D.S, 2008, "A model of peak amplitude prediction for near field blast vibration based on nonlinear charge weight superposition, time window broadening, and delay time modeling," *Blasting and Fragmentation*, Vol. 2, No. 2, pp. 91-115.

Refuge alternatives
relief valve testing and design

by T.J. Lutz, P.T. Bissert, G.T. Homce and J.A. Yonkey

Abstract ■ The U.S. National Institute for Occupational Safety and Health (NIOSH) has been researching refuge alternatives (RAs) since 2007. RAs typically have built-in pressure relief valves (PRVs) to prevent the unit from reaching unsafe pressures. The U.S. Mine Safety and Health Administration requires that these valves vent the chamber at a maximum pressure of 1.25 kPa (0.18 psi, 5.0 in. H_2O), or as specified by the manufacturer, above mine atmospheric pressure in the RA. To facilitate PRV testing, an instrumented benchtop test fixture was developed using an off-the-shelf centrifugal blower and ductwork. Relief pressures and flow characteristics were measured for three units: (1) a modified polyvinyl chloride check valve, (2) an off-the-shelf brass/cast-iron butterfly check valve and (3) a commercially available valve that was designed specifically for one manufacturer's steel prefabricated RAs and had been adapted for use in one mine operator's built-in-place RA. PRVs used in tent-style RAs were not investigated. The units were tested with different modifications and configurations in order to check compliance with Title 30 Code of Federal Regulations, or 30 CFR, regulations. The commercially available relief valve did not meet the 30 CFR relief pressure specification but may meet the manufacturer's specification. Alternative valve designs were modified to meet the 30 CFR relief pressure specification, but all valve designs will need further design research to examine survivability in the event of a 103 kPa (15.0 psi) impulse overpressure during a disaster.

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Background

The Mine Improvement and New Emergency Response Act of 2006, known as the Miner Act (U.S. Department of Labor, 2006), was enacted in the wake of three mine accidents involving explosions or fire that claimed 19 lives that year. Intended to help improve underground coal mine accident preparedness, the Miner Act includes provisions that target mine safety issues in areas such as emergency response planning; adoption of new technology; training and education; and mine safety standards enforcement. Section 13 of the Miner Act specifically directed the U.S. National Institute for Occupational Safety and Health (NIOSH) to provide for research into the effectiveness and viability of refuge alternatives (RAs) for underground coal mines, and the U.S. Department of Labor to act on the results of such research, as appropriate. These mandates culminated in the 2009 adoption of changes to the Title 30 Code of Federal Regulations, or 30 CFR, mining health and safety regulations (U.S. Department of Labor, 2008), requiring underground coal mines to supply mine emergency RAs and associated components so as to provide a life-sustaining environment for persons trapped underground. Such RAs can be either self-contained mobile units or built-in-place facilities. The regulatory changes also include provisions establishing requirements for the approval of RAs and their components by the U.S. Mine Safety and Health Administration (MSHA), among which are numerous criteria for providing a safe breathable atmosphere under positive pressure within the RAs. One criterion for maintaining a safe RA atmosphere is the inclusion of an air pressure relief valve that will activate at a maximum of 1.25 kPa (specified as 0.18 psi, or approximately 5.0 in. H_2O), or as specified by the RA manufacturer, above mine atmospheric pressure in the RA (U.S. Department of Labor, 2008).

The primary purpose of the required relief valve is to limit the maxi-

T.J. Lutz, P.T. Bissert, G.T. Homce, member SME, and J.A. Yonkey are mechanical engineer, mechanical engineer, electrical engineer and engineering technician, respectively, at the U.S. National Institute for Occupational Safety and Health (NIOSH), Pittsburgh, PA, USA. **Paper number TP-15-039. Original manuscript submitted November 2015. Revised manuscript accepted for publication June 2016. Discussion of this peer-reviewed and approved paper is invited and must be submitted to SME Publications by Jan. 31, 2017.**

Figure 1

Schematic of setup.

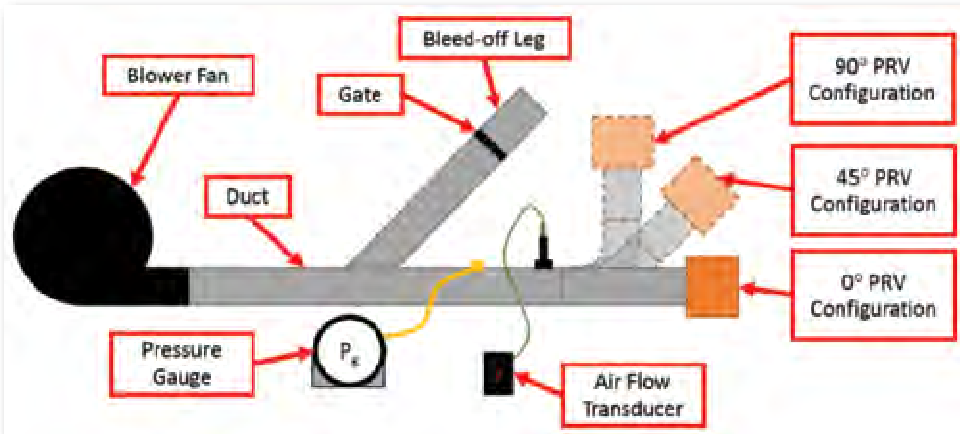

Figure 2

Photograph of setup.

mum positive pressure within the RA to prevent damage to its systems or components as well as provide for occupant safety and comfort during use. Relief valve design and operation, however, must also account for other critical factors, such as meeting minimum RA airflow requirements based on maximum occupancy, preventing reverse airflow before positive pressure is established or if it is lost during RA use, surviving MSHA-specified overpressure and flash fire conditions prior to RA deployment, preventing overpressure that may interfere with personnel entry into and exit from the RA, and in some cases allowing necessary unobstructed airflow prior to RA deployment.

Research to date by the NIOSH Pittsburgh Mining Research Division on mobile RAs as well as built-in-place RA installations for coal mining suggests that the design and implementation of RA relief valves have not yet had sufficient performance analysis or technical development. In response, the division began studying and testing the use of relief valves in RAs. Work thus far has focused primarily on the relief pressure and flow characteristics of a commercially available, purpose-built RA relief valve and adaptations of two relief valve designs normally used in other applications. This paper details the laboratory testing and the specially built test apparatus used to measure and study relief pressures while controlling valve configurations, flow levels and duct characteristics. The testing reported here lays the groundwork for anticipated followup research on valve design reliability, adequacy of valve flow capacity, and valve survivability in the events of overpressures and flash fires.

Experimental setup

To test the performance of a variety of relief valves, a pressure relief valve test stand was developed, consisting of a 1.12-kW (1.5-hp) centrifugal blower fan able to produce a maximum pressure of 1.62 kPa (6.5 in. H_2O) at 24.9 m^3/min (880 ft^3/min), standard ductwork with inside diameters of 10.2 cm (4.0 in.) and 12.7 cm (5.0 in.), candidate pressure relief valves (PRVs), a pressure gauge and an air velocity transducer (Figs. 1 and 2). The blower fan provides the airflow to test each relief valve. The bleed-off leg and gate provide a means to reduce the flow to the relief valve. The pressure gauge and airflow transducer measure the operating parameters of the relief valve being tested. The pressure gauge was installed according to the manufacturer's recommendations, with +/–2 percent mechanical accuracy, and the accuracy of the flow meter is +/–3 percent of reading. Results are verified with a second set of flow and pressure gauges substituted into the test setup. The different angle configurations provide different relief pressures and flows depending on the angle of the flap and resulting force required to open the relief valve.

The system is modular in that its ductwork can be extended or reduced and the valves can be quickly switched out. This allowed for each PRV to be tested at 0°, 45° and 90° orientations, in terms of the angle of flow with respect to horizontal.

The pressure at which the PRV relieved was measured using a Magnehelic gauge rated up to 2.5 kPa (10.0 in. H_2O).

A modular airflow probe adapter was designed and fabricated with a 3D printer, which allowed for the probe to be positioned at various distances from the center of the duct by installing different-sized inserts. An example of one insert is shown in Fig. 3. The air velocity was measured using a Kanomax 6332D air flow transducer. Four different inserts were used to measure the air velocities at distances of 0.0 mm (0.0 in.), 12.7 mm (0.5 in.), 25.4 mm (1.0 in.) and 38.1 mm (1.5 in.) from the center of the duct. Measuring the air velocities at these four locations allowed for the average velocity to be determined across the ductwork cross section. The actual cubic feet per minute, or ACFM, air velocities were measured using the test setup. Standard cubic feet per minute, or SCFM, would change the values by less than 5 percent, so the values were not adjusted. The average velocity for the polyvinyl chloride (PVC) check valve was within 10 percent of all measured velocities, making multiple readings unnecessary for the other relief valves.

Valve designs

Three valve designs were tested using the benchtop setup: (1) A commercially available 10.2-cm (4.0-in.) Schedule 40 PVC check valve (Fig. 4) was tested in its original configuration and modified to increase the relief pressure. These valves are normally used in water systems to prevent backflow in waste water applications. Weights were added to the plastic check valve flap, and the valve was tested in different orientations. The flap seals with an O-ring that is captured in the outer edge of the flap. (2) A brass/cast-iron butterfly check valve (Fig. 5) was modified by removing the torsion springs to lower the relief pressure to an acceptable level and orienting the valve to use the weight of the brass parts to create a relief pressure. These valves are also used for backflow prevention in waste water systems. (3) A commercially available valve that was designed for RAs and is currently installed in steel prefabricated portable RAs and one mine operator's built-in-place RA was also tested (Fig. 6). The valve was tested in as-received condition as well as a modified configuration that aimed to reduce the relief pressure in an attempt to meet the 30 CFR maximum opening pressure of 1.25 kPa (0.18 psi) above mine atmospheric pressure in the RA. The unit is steel cased and has a steel flap design that is spring loaded and sealed with an elastomer gasket.

Measurements and analysis

The setup was used to measure the pressures and air velocities for a number of configurations. Table 1 shows the test results for the NIOSH modified off-the-shelf PVC check valve that had weights added to the lightweight flapper to increase resistance to air flow, allowing for the relief pressure to be controlled by simply adding or removing weights and changing the angle. All values were recorded after airflow was established and had stabilized. Nine configurations in total were tested by adjusting the angle and the amount of weight added to the flapper. Air veloci-

Figure 3

From left to right: Probe adapter, probe adapter with insert, probe installed ready for testing.

Figure 4

PVC check valve.

Figure 5

Brass/cast-iron butterfly check valve.

Figure 6

Commercially available relief valve.

Table 1

Pressure and velocity data for the NIOSH modified PRV.

		XL insert (1.5 in. from center)			L insert (1.0 in. from center)			M insert (0.5 in. from center)			S insert (0 in. from center)			Average		
Angle	Added weight to flapper (kg)	V (m/s)	Q (m^3/min)	P (kPa)	V (m/s)	Q (m^3/min)	P (kPa)	V (m/s)	Q (m^3/min)	P (kPa)	V (m/s)	Q (m^3/min)	P (kPa)	V (m/s)	Q (m^3/min)	P (kPa)
0°	0.00	21.4	16.3	0.3	23.0	17.5	0.3	22.9	17.4	0.3	23.7	18.0	0.3	22.8	17.3	0.3
	0.43	20.0	15.2	0.5	19.9	15.1	0.5	21.0	16.0	0.5	20.9	15.9	0.5	20.4	15.5	0.5
	0.87	18.9	14.3	0.7	19.5	14.8	0.7	20.9	15.9	0.7	20.0	15.2	0.7	19.8	15.1	0.7
45°	0.00	20.9	15.9	0.3	23.2	17.6	0.3	23.0	17.5	0.3	23.8	18.1	0.3	22.7	17.3	0.3
	0.43	19.7	15.0	0.6	21.5	16.4	0.6	21.4	16.3	0.6	22.1	16.8	0.6	21.2	16.1	0.6
	0.87	18.3	13.9	0.7	20.0	15.2	0.7	19.9	15.2	0.7	20.8	15.8	0.7	19.8	15.0	0.7
90°	0.00	21.1	16.0	0.3	22.3	16.9	0.3	22.4	17.0	0.3	23.8	18.1	0.3	22.4	17.0	0.3
	0.43	21.9	16.6	0.4	21.3	16.2	0.4	22.9	17.4	0.4	22.3	17.0	0.4	22.1	16.8	0.4
	0.87	19.7	15.0	0.5	22.4	17.0	0.5	22.5	17.1	0.5	21.7	16.5	0.5	21.6	16.4	0.5

ties were measured using all four of the different velocity probe inserts at all nine configurations. The volumetric flow rate was calculated based on the cross-sectional area of the 10.2-cm (4.0-in.) ductwork at the PRV. The air velocity was corrected for the ductwork reduction based on the Venturi effect and continuity equation (Pope, 1996):

$$Q = v_1 A_1 = v_2 A_2$$

where Q is the flow rate in m^3/s, v is the velocity in m/s and A is the cross-sectional area of the pipe in m^2.

From the results of changing the angle in conjunction with the added weight shown in Table 1, it can be seen that the relief pressure can be adjusted up or down within the MSHA requirements as desired.

Table 2 shows the test results for the brass/cast-iron butterfly PRV. Two different configurations were tested: (1) 45° orientation with no spring return and (2) 90° orientation with no spring return. For both configurations, the air velocities were measured at the center of the ductwork. The unit was not tested at 0° because it would not be capable of sealing without a spring return. For the 45° configuration, the pressure relieved right at the 30 CFR limit of 1.25 kPa (5 in. H_2O). For the 90° configuration, the pressure exceeded the 30 CFR limit.

Table 3 shows the test results for the commercial PRV that was purpose-built for RAs. Three different configurations were tested: (1) original, or as-received, (2) with preload washers removed and (3) with the factory spring replaced with a 17.9-g/mm (1-lb/in.) spring and a washer.

For all three configurations, the air velocities were measured at the center of the ductwork. Pressures exceeded the limit of 1.25 kPa (5.0 in. H_2O) for all three configurations. The most noteworthy result of this testing is that this unit did not relieve any pressure up to 1.62 kPa (6.5 in. H_2O), the maximum pressure available for the test apparatus, in the original configuration. Even with modifications to reduce the load on the valve by replacing the spring, the unit did not relieve until 1.44 kPa (5.8 in. H_2O). The manufacturer was contacted and stated the valve was not calibrated. They use a compressed air source that only allows testing of the opening pressure of the valve and not airflow. The users of this commercially avail-

Table 2

Brass/cast-iron butterfly PRV test results.

Angle	Configuration	V (m/s)	Q (m^3/min)	P (kPa)
45°	No springs.	15.1	11.5	1.25
90°	No springs.	14.1	10.7	1.30

Table 3

Commercial PRV test results.

Angle	Configuration	V (m/s)	Q (m^3/mln)	P (kPa)
0°	Original.	0.0	0.0	1.62
	Preload washers removed.	0.0	0.0	1.62
	Factory spring replaced with 1-lb/in. spring and washer.	11.3	8.6	1.44

able RA valve did pass purge testing for a portable RA during their harmful gas removal component testing. The valve was only tested at the 0° orientation because the other angles would have increased the relief pressure due to the weight of the flap.

Although the adequacy of RA relief valve flow capacity has not been directly addressed at this stage, the test results do begin to shed light on this topic. Specifically, 30 CFR requires an airflow of at least 0.35 m^3/min (specified as 12.5 ft^3/min), per occupant to a built-in-place RA when breathable air is supplied by compressed air cylinders, a fan or a compressor. The average flow rate for the modified PVC check valve configured at 45° with no added weight (Table 1) represents a breathable air throughput sufficient for approximately 49 RA occupants.

Discussion

Testing was conducted on three different valve designs to be used for pressure relief in built-in-place RAs. Two of the units, a PVC check valve and a brass/cast-iron butterfly check valve, were purchased off the shelf and modified to evaluate compliance with 30 CFR regulations for relief pressure. A commercially available valve that was designed for steel portable RAs and is currently installed in a number of mines was also examined.

Of the three PRVs tested, only the modified PVC check valve complied with the 1.25 kPa (0.18 psi, 5.0 in. H_2O) limit. The commercially available valve would not operate at the test setup maximum pressure of 1.62 kPa (6.5 in. H_2O) until a lighter spring was installed, although the relief pressure was still above the 30 CFR limit. The manufacturer did demonstrate the ability to purge with this valve installed in a portable RA, in previous testing. Additionally, the airflow through the PVC check valve as tested is sufficient to meet the built-in-place RA requirement of 0.35 m^3/min (12.5 ft^3/min) per RA occupant, for RA capacities as high as 49 people.

The purpose of the testing was to investigate the airflow and pressure relief characteristics of the three PRVs. No research was performed on the survivability of the PRVs to comply with the 103 kPa (15.0 psi) impulse overpressure specification. Future research is necessary to address the survivability of PRVs and may warrant significant valve housing and flap redesign.

Conclusions

The commercially available valve that was tested is used in steel prefabricated portable RAs and one mine operator's built-in-place RA. The vast majority of PRVs that are in use are servicing tent-type units and were not part of this research. The commercially available relief valve does not comply with the 1.25 kPa (0.18 psi) limit as stated in the 30 CFR specifications but may meet specifications set by the manufacturer. This valve needs to be reevaluated by the manufacturer to ensure it meets the 30 CFR specifications.

The PVC check valve that was tested offers a viable solution for relief valves in RAs. It can be modified to adjust the relief pressure as needed. The size of the relief valve can be chosen to allow sufficient airflow out of the RA to meet the airflow requirement based on the number of miners in the chamber.

The brass/cast-iron butterfly check valve may be an alternative to the PVC check valve with further modifications.

Future research is necessary to examine the survivability of PRVs subjected to a 103 kPa (15.0 psi) impulse overpressure. The PVC check valve housing and flap may need to be redesigned in order to withstand the mine atmosphere and a potential catastrophic event. ■

Disclaimer

The findings and conclusions in this report are those of the authors and do not necessarily represent the views of NIOSH. Reference to specific brand names does not imply endorsement by NIOSH.

Acknowledgments

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References

Pope, J.E., 1996, *Rules of Thumb for Mechanical Engineers*, http://dx.doi.org/10.1016/b978-088415790-8/50014-x.

U.S. Department of Labor, 2006, "Mine Improvement and New Emergency Response Act of 2006 (Miner Act)," http://arlweb.msha.gov/MinerAct/MinerActSingleSource.asp.

U.S. Department of Labor, 2008, "30 CFR Parts 7 and 75, Refuge Alternatives for Underground Coal Mines," http://www.msha.gov/REGS/FEDREG/FINAL/2008finl/E8-30669.pdf.

U.S. Department of Labor, 2008, "30 CFR 7.506(c)(1)."

New Products

McLanahan introduces MD vibratory screen

McLanahan's MD vibratory screen.

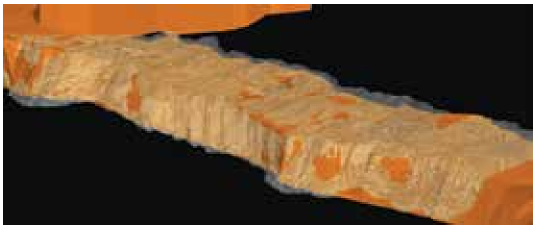
McLanahan Corp. has built a reputation as a trusted screen provider for many industries but is now introducing its own product line called the McLanahan MD vibratory screen. The new screen is a compact, high-capacity, dry screening unit that can be used efficiently and effectively with dried sand, iron ore, quick and burnt lime, limestone and gypsum.The MD vibratory screen gives producers more tons per hour per square feet of screen surface area and handles much larger capacities than conventional screens while occupying the same, or less, floor space. Additionally, it is capable of making multiple product sizes simultaneously, as progressively smaller material sizes are separated from deck to deck.

The screens are available in widths ranging from 5 to 200 cm (19 to 78 in.) with one to five screen decks, depending upon the application. It is capable of handling feed sizes as large as approximately 7.6 cm (3 in.) and can make size separations down to approximately 250 mu (60 mesh). McLanahan's design concept for this screen reduces the risk of pegging and blinding, while achieving high capacities due to its ability to make a separation at a given size using a mesh aperture of greater size.

To provide an even longer screen life, larger particles are removed by heavier, larger screens, while finer screens see only smaller particles and only a portion of the incoming feed.

www.mclanahan.com

Deswik includes mobile 3D scanning tool in new software


uGPS Rapid Mapper data (translucent) is superimposed on a typical survey as-built triangulation, visualized in Deswik.

Deswik has included new mobile 3D scanning tools in its newest software release, version 2016.2. The product launch took place at the International Congress for Mine Surveying in Brisbane, Australia this September.

3D mobile scanning is a rapid and effective solution for a variety of underground survey applications. Deswik has partnered with Peck Tech Consulting Ltd., whose offerings include the uGPS Rapid Mapper. This product was designed and built for an underground environment and can generate 3D point clouds from virtually any moving platform: a mine vehicle, a load-haul-dump machine, an all-terrain vehicle or even a remotely operated robotic vehicle.

A uGPS Rapid Mapper unit has been deployed at the Goldcorp Hoyle Pond Mine site near Timmins, ON, Canada since May 2016. Feedback from the surveyors on site has proven invaluable in developing a streamlined, integrated workflow in the new Deswik version 2016.2. The mapper unit is used to rapidly collect 3D point cloud data in the field and can be imported, meshed and ready for analysis in Deswik with a few clicks of the mouse. The new suite of powerful analysis tools can then be used to georeference and align scans, obtain rapid drift dimensions for ventilation or project engineering purposes, calculate volumes, investigate the incidence of overbreak/underbreak, determine shotcrete thicknesses to control overspray and more. These rich data sets also include intensity information that can be highlighted within Deswik to reveal a variety of important features, such as survey targets, ventilation tubing, utility pipes, rock bolt plates, water infiltration, cracking in shaft liners and even geological nuances for mapping purposes.

www.deswik.com

Oxifree products extend equipment life

Oxifree Global exhibited its thermoplastic coating, Oxifree TM198, at the recent MINExpo in Las Vegas, NV. The coating protects metal components used in the mining industry that are susceptible to corrosion and abrasion from natural and artificial elements, extending the life of conveyor pulley and bearing systems.

The cost of contamination in mining can be considerable, with asset owners frequently replacing equipment after only a few months. TM198 has been proven to extend the life of this equipment by up to 10 times, with great success. Oxifree's Oxitape is another product offered to make the maintenance of components easier and more cost effective. It is applied over the Oxifree TM198 coating to create a defensive barrier and ensure complete protection from contact, corrosion and contamination. It is ideal for use in areas subject to impact and abrasion both above and underground.

Both Oxifree products can be easily removed and then reapplied, making them ideal for inspections, maintenance and small touch-ups in the field.

www.oxifree.com

Yokohama's New R69 OTR radial tire offers higher speeds, heavier loads

Yokohama Tire Corp.'s new R69 L5-S off-the-road radial tire for loaders in underground mine applications is now available in size 18.00R25.The tire was recently displayed at Yokohama's booth at MINExpo. The R69 was designed to reduce downtime and increase efficiency. It is engineered for endurance and is the ideal tire for increased speed and loads during long-haul mining operations.

Benefits of the R69 L-5S include improved durability by using advanced compounds that resist heat build-up and fight cuts and chips. The tire offers superb cut-resistant tread and a longer service life thanks to a durable belt package, along with enhanced compounds that deliver a durable and stable footprint. It also provides added protection in underground mining excavations due to a high-angle sidewall that increases thickness and decreases sidewall stress. The R69 L-5S has a stronger casing and more extensive rim contact area using high-tensile-strength bead cores that lower bead stress and reduce the potential for slippage.

www.yokohamaotr.com

The R69 L-5S off-road radial from Yokohama.

VALE uses Immersive Technologies' simulation equipment to train truckless system operators

The S11D project in Canaã dos Carajás, Pará, Brazil will begin truckless mining production in 2016, and this new production method requires an advanced solution for operator training. Immersive Technologies, a leader in mining equipment simulators, will provide high-tech simulators for mining equipment and customized virtual training environments for VALE's loading machine operators, enabling the incorporation of new procedures to ensure a safe and productive operation.

The truckless system represents a significant change in the role and expertise of the loading equipment operators, which required a custom Immersive Technologies training solution. In conventional mining operations, the trucks are positioned carefully to suit the loading equipment. But when operating with mobile crushers, it is required that auxiliary equipment move the crushers, which remain static during the loading operation. Through advanced training methods using the latest technology simulators, operators will be prepared for the new challenges of productivity and safety. With customized scenarios, Immersive Technologies' simulation equipment will facilitate the development and use of correct procedures for truckless system excavators, optimizing new operator skills and competence.

www.immersivetechnologies.com

Unlike traditional mines, S11D will be a truckless operation that will use Immersive Technologies' simulators to train operators in a more productive and safe way in a unique environment.

Split Engineering introduces the next generation of its Split-Online system

Split-Online is an industry-approved standard for automated, coarse-rock fragmentation size measurement systems and has been installed at more than 140 mine operations with more than 560 camera locations on five continents. Split-Online provides an online measurement of the particle-size-distribution (PSD) information from post-blast muck piles to primary crusher feed to mill recycle. Optimizing fragmentation during blasting and controlling the crushing and grinding circuits can often achieve substantial benefits in improved performance or reduced costs. The Split-ShovelCam system extends the Split-Online software for operation on mobile excavation equipment, such as cable shovels and hydraulic excavators.

The new Version 5.0 software includes a dashboard that presents particle-size results in a web browser for immediate data access, quality control and live-image viewing. Additional color and brightness information measurements provide new opportunities for ore and rock type identification. Other options enable custom settings for different operating conditions, such as day/night for ambient light cameras and custom calibration settings for different ore and rock types.

The Split-Online system can maximize the crushing and conveying process by quantifying fragmentation to improve operation efficiency and increase product recovery.

Split Engineering directly designs, installs and supports its online systems, and its size algorithms have been validated and vetted by the industry for almost 20 years. ■

www.spliteng.com

Coming Events/Short Courses

Upcoming SME Events

Cutting Edge: Advances in Tunneling Technology
Nov. 6-9, 2016
Concourse Hotel at Los Angeles Airport
Los Angeles, CA, USA

2016 Arizona Conference
Dec. 4-5, 2016
JW Marriott Tucson Starr Pass Resort and Spa
Tucson, AZ, USA

George A. Fox Conference
Jan. 24, 2017
Graduate Center
City University of New York
New York, NY, USA

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

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

October 2016

9-12 • Underwater Mining Conference 2016
Orakai Songdo Park Hotel, Incheon, Korea
Phone: 808-956-5095
email: karynnem@hawaii.edu
www.underwatermining.org

10-12 • 13th AusIMM Mill Operators Conference
Pan Pacific Hotel, Perth, WA, Australia
Phone: 61-3-9658-6105
email: esanneman@ausimm.com.au
www.milloperators.ausimm.com.au

10-14 • Sampling Theory, Sampling Practices
Colorado School of Mines, Golden, CO, USA
Phone: 303-279-5563
email: space@mines.edu
www.csmspace.com

11-13 • 31st SME Florida Section Regional Conference
Lakeland Center, Lakeland, FL, USA
Phone: 863-514-7108
email: floridasme@gmail.com
www.smefloridaconference.com

18-20 • Heap Leach Solutions 2016
JW Marriott Hotel, Lima, Peru
Phone: 604-683-2037
email: heapleach@infomine.com
www.mining.solutions/heapleach

18-21 • 24th World Mining Congress 2016
SulAmerica Business Center, Rio de Janeiro, Brazil
Phone: 55-21-2432-6644
email: fernanda@hyrnastha-inovar.com.br
www.wmc2016.org.br

19-21 • Mining & Engineering Indonesia 2016
Jakarta International Expo, Jakarta, Indonesia
Phone: 61-2-9422-2572
email: michael.mcalister@reedexhibitions.com.au
www.miningandengineeringindo.com

25-27 • OMOC Americas
St. Andrews Club & Conference Center, Toronto, ON, Canada
Phone: 44-0-207-216-6080
email: cs@resourcefulevents.com
americas.miningoptimization.com

26-28 • Procemin 2016
Sheraton Hotel, Santiago, Chile
Phone: 56-2-2652-1532
email: procemin@gecamin.com
https://gecamin.com/procemin/english

31- Nov. 2 • Monitoring and Modeling Mining Solutions
North Vancouver, BC, Canada
Phone: 1 604 683 2037 ext. 231
email: monitoringandmodelling@infomine.com
http://mining.solutions/monitoringandmodelling

November 2016

6-10 • Sustainable Industrial Processing Summit
Sanya Marriott Yalong Bay Resort, Hainan Island, China
Phone: 514-344-8786
email: symposiums@flogen.org
www.flogen.org/sips2016

13-15 • Graphite Supply Chain 2016
The Island Hotel, Newport Beach, CA, USA
Phone: 44-0-7905-771-494
email: ismene@informed.com
www.benchmarkminerals.com/graphite2016

13-16 • Copper 2016
Kobe International Convention Center, Kobe, Japan
Phone: 81-3-3402-0541
email: cu2016@mmij.or.jp
www.copper2016.jp

14-15 • Silver and Gold Summit
Park Central Hotel, San Francisco, CA, USA
Phone: 604-687-4151 • Fax: 604-687-4726
email: info@cambridgehouse.com
http://cambridgehouse.com/event/53/the-silver-and-gold-summit-2016

15-16 • 9th AusIMM Open Pit Operators Conference
Western Australian School of Mines Conference Center
Kalgoorlie, WA, Australia
Phone: 61-3-9658-6105
email: esanneman@ausimm.com.au
www.openpitoperators.ausimm.com.au ■

SME introduces Move Mining competition

SME has launched a campaign designed to improve the public perception of the mining industry. Move Mining is a team competition open to students and professionals who wish to develop a positive message campaign to promote the benefits of mining worldwide.

Key legislators and decision makers around the world do not understand the essential role that mining plays in our lives, our lifestyles and our standard of living. "Move Mining is an innovative approach to tap into the broad experience of SME members to help communicate the global benefits of mining and improve the public perception of the industry," said Red Conger, president and chief operating officer, Americas and Africa Mining, Freeport-McMoRan. "Our products sustain society, and Move Mining will help us come up with new ways to share that message."

The method of delivery is the key to the competition. Innovation and imagination on how to visualize the message, and then convey it to the world, will help the successful candidates.

By Dec. 1, 2016, participating teams will create and submit a five-page concept paper, in English, focused on promoting a positive message and the global benefits of the mining industry. The top five teams selected will pitch their ideas to a panel of industry leaders and communication experts at the SME Annual Conference & Expo and CMA 119th National Western Mining Conference in February 2017.

Members of the judging panel will consider the following criteria in making their selections: creativity in the content selection and presentation; anticipated breadth of public appeal and interest; and effectiveness in describing the concept and its impact on people and society.

The winning team will receive a $5,000 cash prize and support from SME and sponsoring organizations to help promote and package its winning concept during 2017. Two free conference registrations will be provided to the concept presenters on each team. Teams are encouraged to bring props, samples and other presentation materials. Presentations must not exceed 15 minutes.

Keep some general guidelines in mind when developing and writing the concept paper.

- Approach — what is your team's idea?
- Implementation — how does your team plan to meet the goal of improving the public perception of mining?
- Reach — who is the target audience, and why are you taking this approach?
- Resources needed — what monetary and other resources are needed to implement the approach? Include a draft budget on how money will be spent.

Eligibility

The competition is open to individuals or teams in the following four categories: (1) mining industry students, (2) SME local sections, (3) SME student chapters and (4) mining industry professionals. Entrants may submit more than one concept paper. By entering a submission in the contest, each individual entrant and each team member agrees to comply with and be bound by the official rules and decisions of SME.

For additional information on presenting guidelines,

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Personal News

The National Stone, Sand & Gravel Association (NSSGA) has selected **IAN REYNOLDS** (SME), a senior at the Missouri University of Science & Technology, as the recipient of its 2016 Barry K. Wendt Memorial Scholarship. The scholarship is awarded by NSSGA's Manufacturers & Services Division and is presented annually to an outstanding college student who plans to pursue a career in the aggregates industry. Reynolds has worked in several quarries, including a recent co-op with NSSGA member Mississippi Lime Co., and he is pursuing a degree in mining engineering with an emphasis on quarrying. He is vice president of his school's student chapter of NSSGA and has participated in the NSSGA/SME Student Design Competition.

Gomez International has hired **CHRIS S. RHOADES** as director of sales and business development. Rhoades was formerly director of sales for Brookville Equipment Corp. He will be working remotely from Pennsylvania.

BILL DAVIDSON has retired from Tsurumi Pump. He was district manager for ASH

(Continued on page 65)

SME Foundation offers

2017 VIP all-access conference pass

Did you notice attendees at the 2016 Annual Conference & Expo wearing a special VIP Access badge? Are you wondering how to get yours for the upcoming conference & expo in Denver? Donate $1,000 or more to any SME Foundation program during the 2016 calendar year, and we will show our gratitude for your support with a VIP Access badge.

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- Free admission to the international reception.
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Partner with the SME Foundation in support of its essential programs, and we will treat you like a VIP. Donate online at smefoundation.org or send your contribution to the SME Foundation, 12999 E. Adam Aircraft Cir., Englewood, CO 80012, phone 303-948-4200, email foundation@smenet.org. ■

Apply online now for SME scholarships

by Rachel Grimes, Sections and Division Coordinator

Do you need money for school? Are you a sophomore, junior, senior or graduate student? Is your mining-related program ABET-accredited? Does your school have an active SME Student Chapter?

If you answered “yes” to these questions, check out SME’s available scholarships at www.smenet.org/students/grants-scholarships.

2016 Scholarships — apply by Oct. 15

- Coal & Energy Division Scholarship and John Sidney Marshall Scholarship.
- Environmental Division Scholarship and Veolia Water Technologies Scholarship.
- Ernest K. Lehmann Memorial Scholarship.
- Gerald V. Henderson Memorial Scholarship.
- Henry DeWitt Smith Graduate Scholarship (M&E Division).
- Mineral & Metallurgical Processing Division Scholarship and Richard Klimpel Memorial Scholarship.
- McIntosh Engineering Scholarship and J.H. Fletcher & Co. Scholarship.
- Mining & Exploration Division Scholarship and Eugene P. Pfleider Scholarship.
- MMSA/SMEF Presidential Scholarship.
- Rong Yu Wan Ph.D. Dissertation Award.
- Steven C. Potter Scholarship.
- Stewart R. Wallace Memorial Scholarship (M&E Division).
- Syd S. and Felicia F. Peng Ground Control in Mining Scholarship.
- UCA of SME Scholarship.
- WAAIME Scholarship.

Find specific guidelines for each of the scholarships and apply at www.smenet.org/students/grants-scholarships. Scholarship applications must be completed using the SME online application portal. The application deadline for most scholarships is Oct. 15, 2016. The deadline for the UCA of SME Scholarship is Nov. 15, 2016.

Questions about SME scholarships may be directed to scholarships@smenet.org. ■

Charles Kliche and John Scheetz are Local Section Heroes

Local sections are an integral part of SME. They provide a forum for SME members to gather, to facilitate the exchange of information and to increase grassroots participation in SME programs and services. Through involvement in a local section, members have the opportunity to network with their peers and to hear valuable presentations.

At the core of each local section is a group of dedicated volunteers who recruit members, organize section activities, work with local SME Student Chapters, raise money, provide educational outreach and more. To recognize our member volunteers for their hard work at the local section level, SME has created the Local Section Hero Award. This column highlights an individual who has carried out unique, exemplary or long-standing service to a local section.

If you know someone who is providing exemplary service to your local section, visit www.smenet.org/membership/groups/local-sections, click on Local Section Hero Awards and nominate that individual as a Local Section Hero.

Charles Kliche (l) and John Scheetz (r) of the Black Hills Local Section.

Charles Kliche and John Scheetz, Black Hills Local Section

The Black Hills Local Section of SME went into a decline in the late 1990s and early 2000s due to the progressive closure of the Homestake Mine, low commodity prices, especially gold, and waning interest in attending meetings. The last Section officer in the area was John Scheetz who, in 2003, elected to freeze the chapter assets and to wait until interest in the chapter revived. Scheetz was the Homestake/Barrick environmental manager at the time.

Scheetz and Charles Kliche, professor at the South Dakota School of Mines and Technology (SDSM&T), spoke regularly, about once a year, about getting the Section up and running again. In 2013, Kliche received a note from SME headquarters inquiring if the Section was still active and, if so, who were the current the officers. Kliche contacted Scheetz, who is now working at the Sanford Underground Research Facility (formerly the Homestake Mine), and it was jointly decided that it would be an opportune time to restart the chapter due to the resurgence of mining interest at SDSM&T and in the northern Black Hills. Kliche had maintained a spreadsheet of contact information for people in the vicinity who might be interested in attending Black Hills SME meetings. The spreadsheet was updated fairly regularly whenever people left the area or new people interested in mining came into the area.

Kliche and Scheetz chose the names of about 20 good, reliable people to produce an “interested parties” list and sent out a notice about a meeting to get the Section revived. Within that group, a slate of officers and directors were nominated and, not surprisingly, Kliche was elected president and Scheetz elected treasurer. The first meeting of the renewed section was held at the Lodge in Deadwood, SD and was attended by about 80 people, including about a dozen SME student members from SDSM&T.

At that initial meeting, it was decided that the chapter’s mission would be to support and encourage students to pursue careers in mining and mining-related studies. An effort was made to find sponsors for each meeting. Any sponsorship money or raffle money raised at the meeting was used first to buy dinner for the students and then to fund scholarships or student travel to sponsored events, such as the SME Annual Conference and Expo, the ISEE annual meeting or intercollegiate mining competitions. In 2015, the Black Hills Local Section provided more than $4,000 to SDSM&T student organizations and gave subsidies to all students attending SME meetings or dinners.

Four meetings were held the first year, rotating between Rapid City and the Northern Black Hills,and three meetings were held the second year. The number of meetings varies due to interest and speaker availability. Attendance is usually between 50 and 80 people. Speakers generally talked about projects of local interest.

At the last meeting in 2016, Kliche passed the leadership baton to Ken Wrede, and Cody Vining took over as treasurer from Scheetz. The outlook for the Section is good, and its mission is solid. ■

Personal News

(Continued from page 63)

Pump from 1969 to 1978 then started his own engineering sales company, Tsurumi Distributors, in 1989. Tsurumi Pump acquired his company in 2008, naming Davidson as its North American general manager. **CHUCK RICKMAN** will assume Davidson’s responsibilities as the new vice president of sales. He will work directly with regional sales managers to establish new distribution channels. ■

Make it as much fun as the first time

Why you should attend the SME Annual Conference & Expo

by Mark K. Jorgensen and Garland Davis

Do you remember your first SME Annual Conference & Expo? It was all new and exciting. The vendors and their bags of swag were great. And what better way to collect pens for the entire year; or attend a technical session and have the expert respond to your thought-provoking question; or enjoy the meal at the Mineral & Metallurgical Processing Division (MPD) luncheon and realize you were sitting next to the author of a prized (and expensive) textbook; or find out that the chief executive officer of your company was drinking the same beer as you do. What a great experience.

The annual conference can be exciting the first time but, as you progress in your career, it may be time for a new and different experience. One of the great strengths of SME is the opportunity to share and give back some of the knowledge that you have recently developed. This is something important to us all, and it is something that the Annual Conference lets each of us do in a different way. There are a number of different ways that you can make a difference. Here's the short list.

Be a mentor to a student. Show them around. Introduce them to your friends. Help them choose and attend a technical session. Show and explain to them what is important in the exhibit hall. Bring your mentee to an SME committee meeting. It is so important that students have a good experience at the convention, and you can be a big part of that.

Volunteer to be on one of the planning committees for next year's technical sessions. There are five committees, Comminution, Plant Design, Chemical Processing, Physical Separations and Flotation. The meetings for these committees will take place on the Sunday afternoon, and MPD always needs volunteers for these committees. Almost 90 percent of the talks presented at SME come from volunteers solicited by these committees.

Volunteer to be on one of the MPD committees. There are 27 committees that MPD must staff every year. If you are willing, there is a spot for you. A past president of MPD, Richard Johnson, is responsible for organizing and presenting names to the executive committee.

Offer to present a paper at the next SME Conference. It is too late to get a paper submitted this year, but we will be starting to look for new papers the day after the SME Conference ends. As mentioned previously, the committee meets Sunday afternoon, prior to the start of the conference.

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 2016 is Mark K. Jorgensen.

Three more suggestions ...

In addition, you can take a short course for Professional Development Credits, attend the SME Foundation Dinner and submit a meaningful bid in the blind auction or learn about and taste single-malt scotch at the MPD Scotch Nightcap.

Are you making plans to attend the 2017 SME Annual Conference & Expo and CMA 119th National Western Mining Conference in Denver, blocking out your calendar for Feb. 19-24? It will be here quicker than you think. It's always a good time and, hopefully, you'll return home with a bit of new information and beneficial experiences.

But maybe you have attended a few of these conferences, and you are thinking that maybe this is a bit of déjà vu? You already know many of the vendors and exhibitors, and how many alumni meetings can you attend? Perhaps one old friend too many? And why listen to another paper presented by an environmental engineer from your company just to show support?

Break that routine. We invite you to attend but with a fresh mindset, willing to expand your bounds and experience SME in a new way, just like the first time. Registration details and other information can be found on the SME website, www.smenet.org, or the conference website, www.smeannualconference.com. ■

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Kylie Ashenbrenner, Minneapolis, MN
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Araina Boyd, Embarrass, MN
Erick E. Caballero Z., Lima, Peru
Kevin D. Cacallace H., Tacna, Peru
Reid Castrodale, Concord, NC
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Paula Giryn, Virginia, MN
Jarom K. Gleed, Salt Lake Cty, UT
Marcela Gotelip B., Maizieres les Metz, France
Geoffrey T. Hilt, Morenci, AZ
Susan Hosseini, Isfahan, Iran
Negin Houshmand, Tehran, Iran

(Continued on page 68)

MEC partners with AGI

Earth Science Week looks at mining and money

by Rebecca Smith, MEC Curriculum Coordinator and Tanya Kriss, MEC Outreach Coordinator

Again this year, the Minerals Education Coalition (MEC) will partner with the American Geosciences Institute (AGI) to provide educational resources to science teachers as part of AGI's Earth Science Week (ESW). Since October 1998, the American Geosciences Institute has organized this national and international event to help the public gain a better understanding and appreciation for the earth sciences and to encourage stewardship of the Earth. This year's Earth Science Week will be held from Oct. 9-15 and will celebrate the theme, Our Shared Geoheritage (www.earthsciweek.org/about-esw).

Earth Science Week — celebrating the geosciences

In addition to international dissemination of the educational toolkits and free, online resources, AGI's Earth Science Week has prompted a new infographic. The rolling, responsive Mining and Money Timeline at www.mineralseducationcoalition.org/esw illustrates mining and money milestones from 1785 through the present.

Mining and Money Catcher.

For inclusion in the 2016 ESW toolkit, MEC has created the colorful Mining and Money Catcher for students to fold and play as they learn about the interrelated history of mining and the money we use every day.

As students play the game, they learn mining vocabulary words, as well as historical facts about how coins get from the mine and into circulation. The relationship between gold and silver discoveries and the development of U.S. Mint facilities is made clear as the game unfolds. These full-color catchers are intended to be a fun, interactive way for students to see how our geoheritage has a history and how it continues to impact daily life.

A 2017 calendar will also be included in the ESW packet. The calendar displays a geoscience-themed activity for each month. MEC's page is a density lesson reproduced with permission from the Nevada Mining Association. In the lesson, students explore density by first estimating it. They calculate the density by finding the mass, by measuring the volume using water displacement and, finally, by applying the formula to these measurements. To link this concept to geoheritage, MEC discusses gold panning on the calendar page as well. Due to its much higher density, gold can be separated from the sediment in which it is found by panning. This lab activity allows students to apply scientific and mathematical techniques to explore the scientific principle of density.

Through this partnership with AGI, the educational resource toolkits are available for purchase internationally. The same resources will be shared on www.earthsciweek.org, www.smenet.org, www.mineralseducationcoalition.org and through SME and MEC social networking channels.

ESW — What can YOU do?

MEC has created these educational resources to introduce students to mining and possible careers in the mining and minerals industries. Combined with the lessons learned from www.mineralseducationcoalition.org, students can become critical thinkers who understand the importance of mining and minerals in everyday life.

SME members, Sections and Student Chapters can help to increase the reach and impact of these educational resources by:

- Purchasing ESW toolkits from www.earthsciweek.org to be distributed to local science teachers.
- Sharing ESW learning activities from www.earthsciweek.org.
- Using the MEC calendar activity and catcher as conversation starters for teachers and students.
- Purchasing MEC's resources, including colorful, content-rich posters that depict mining and minerals from www.mineralseducationcoalition.org/store to provide to schools and for community presentations.
- Playing the podcasts from www.mineralseducationcoalition.org/careers-mining for others who may want to learn more about careers in the mining industry.
- Sharing the Money and Mining Timeline infographic at www.mineralseducationcoalition.org/esw with students.
- Following @MECeducation on Twitter and liking the Minerals Education Coalition Facebook page. Share the ESW resources and other educational content on these channels.
- Contacting MEC outreach coordinator, Tanya Kriss, at 303-948-4221 or kriss@smenet.org to learn more about AGI's Earth Science week and other educational partnerships. ■

SME sponsors young professionals for Emerging Leaders Alliance

SME is sponsoring eight members to the ninth annual Emerging Leaders Alliance (ELA) conference, Nov. 9-12, 2016, in Falls Church, VA. The ELA is a partnership among engineering and science-based organizations that provides an interdisciplinary forum for high-quality leadership training for young professionals and advances the development of highly skilled leaders.

Representing SME in the Class of 2016 are:

- **Manuel Montenegro**, mine planning graduate, MMG – Las Banbas, Lima, Peru.
- **Vasu Grande**, mining engineer, NIOSH, Pittsburgh, PA.
- **Luis Felipe Velasquez**, technical support engineer, Ferreyros S.A., Lima, Peru.
- **Axel Gallegos Gutierrez**, mine planning engineer, Minera Yanaquihua S.A.C., Lima, Peru.
- **Joe Waite,** project engineer, Lehigh Hanson, Inc., Irving, TX.
- **Jorge Loy Benitez**, support engineer, SOMILOR S.A., Guayaquil, Guayas, Ecuador.
- **Mohammad Rezaee**, postdoctoral research associate, Virginia Tech, Blacksburg, VA.
- **Marion King**, mine engineer, Imerys, Lompoc, CA.

During the three-day conference, attendees will undergo intensive training courses such as: Making the Transition from Technical to Management; Building Highly Productive Relationships That Matter; Performance Management; and Emotional Intelligence.

The ELA has been supported by the United Engineering Foundation and organized by nine partner societies. For more information about the Alliance, visit http://emergingleadersalliance.org. ■

Haver & Boecker hosts mining students

Haver & Boecker, maker of mineral processing systems in St. Catherines, ON, Canada, gave 27 University of Toronto (UT) mining engineering students a firsthand look at the industry. Haver & Boecker engineers presented on various aspects of vibrating screens and the screening process before giving the students a tour of the plant to reinforce what they are learning in their university classes.

Dieter Takev, vice president of engineering and technology, and Duncan High, processing equipment technology division manager, walked the students through the basics of screening, screen sizing, vibrating screen mechanical performance and vibration analysis. Their seminars included the history of screening as well as the definition of screening and its phases. Students learned about types of material and screening equipment, the calculations involved in determining optimum performance and the mechanical design of different components.

During the tour of the plant, experts showed the students how to conduct vibration analysis on a running machine.

UT students listen to presentations about screening methods, definitions and history.

The program will continue annually with the University of Toronto. Haver & Boecker (www.haver-canada.com) invites other schools with mining and aggregates programs to contact it for the opportunity to offer their students firsthand industry experience. ■

Membership

(Continued from page 66)

Richie Kennedy, Hibbing, MN
Soraya Keramati, Isfahan, Iran
Aberlardo Layme, Abancay, Peru
Gerardo M. Loayza C., Lima, Peru
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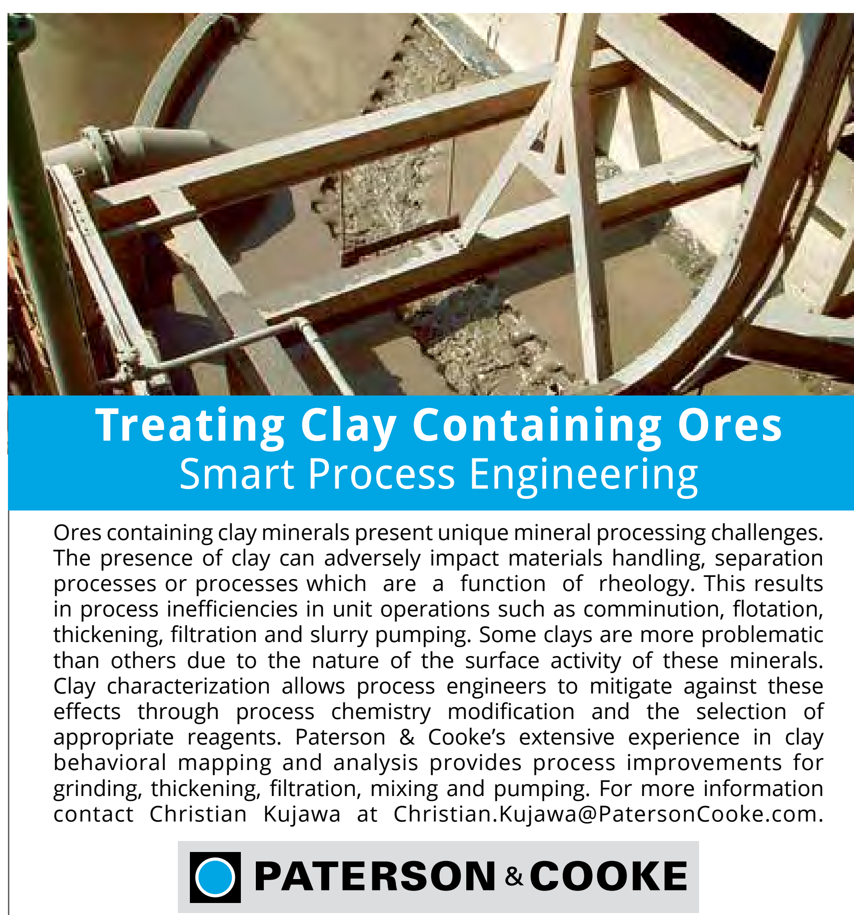
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Rock Engineering Short Courses in December 2016

The following four short courses will be taught by Prof. P. Kulatilake in Tucson Arizona in December 2016 as given below. If you have interest in receiving the brochures of the short courses please send an e-mail to:
kulatila@u.arizona.edu

1. 2-Day course on Rock Fracture Geometry Network Modeling (Dec. 10-11)
2. 2-Day Course on Rock Slope Stability Analyses (Dec. 12-13)
3. 2-Day Course on Block Theory & Applications for Rock Excavations (Dec. 14-15)
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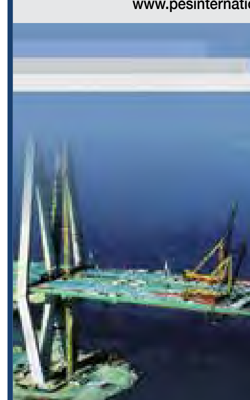

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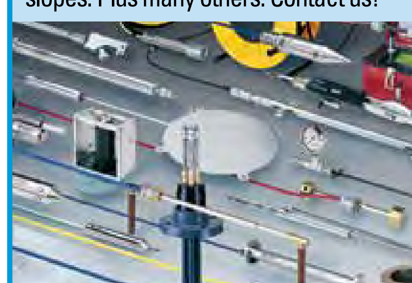

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Two new met coal mines planned

Steve Kral,
Editor

Ramaco
bets on steel

The news from the U.S. coal industry in recent years has been mostly gloomy. Not a new story to those in the mining industry. Major companies like Arch Coal, Alpha Natural Resources and Peabody Energy have each filed for reorganization through bankruptcy. And other coal mining companies, large and small, have either significantly curtailed production or closed mines altogether. All in response to utilities switching to natural gas because of its cheapness, an emphasis on a move to renewables and stricter climate change regulations looming on the horizon. The nation's coal-fired power capacity has fallen by about 15 percent since 2011, according the U.S. Energy Information Administration.

So it was a small amount of good news about two and possibly three new coal mines starting up in the United States.

Ramaco Development, a Kentucky-based company, announced that it will bring on two metallurgical coal mines in Virginia and West Virginia, according the *Associated Press*. The mines will create about 400 new jobs in a region that has an unemployment level about three times the national average. "It's a fairly big deal, frankly, for southern West Virginia," said Randall Atkins, Ramaco's chief executive officer (CEO).

The Elk Creek Mine will be located in southern West Virginia, while the Berwind Mine will be located on the Virginia-West Virginia border. Both will be underground operations and will have expected mine lives of 17 years. The mines are expected to eventually produce about 3.6 Mt/a (4 million stpy) each of metallurgical coal, Atkins said.

Ramaco's CEO told the *AP* that his company believes there is a place in the international steelmaking market for its coal. The price of metallurgical coal has increased some, he said, but even so, Ramaco can make the projects work at fairly low prices, he added. "If we can control costs, the market will take care of itself. So even when you had a very low point, which we've had in past 12 months, our cost is such that we would still be quite profitable."

Prices for U.S. metallurgical in recent years have fallen from $330/t (300/st) to less than $110/t ($100/st), Atkins said. But they recently rebounded some to about $154/t ($140/st).

Romaco obtained a $90-million private equity investment that will allow it to begin test mining next year. And. once it has supply agreements in place, the mines could begin shipping coal in 2018, Atkins said.

Ramaco is also trying to build a third coal mine in northern Wyoming, where most of the coal mining is done on the surface. The proposed Brook underground mine would supply its coal to electric power producers.

Now, the opening of a pair of relatively small coal mines does not mean a resurgence of the domestic coal industry. But it's refreshing to hear some positive news. ■