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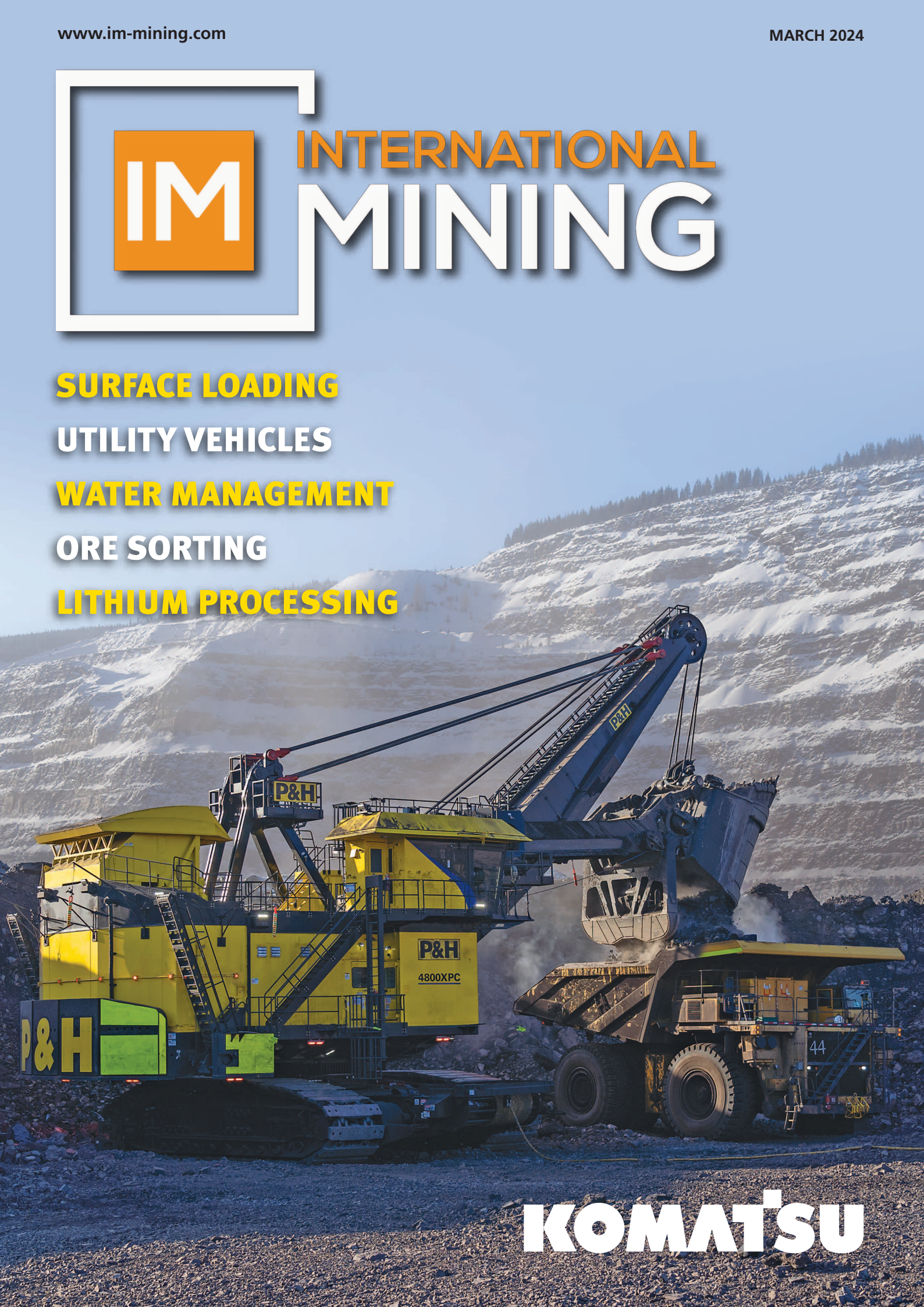

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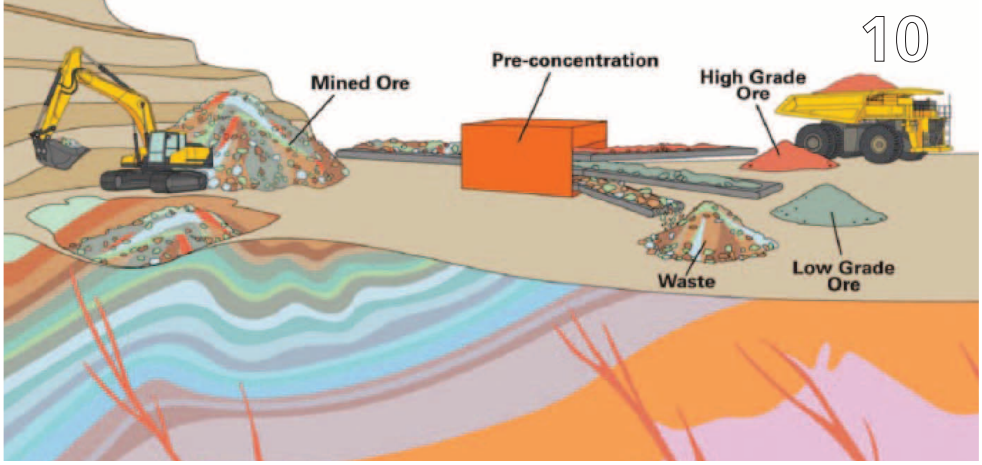

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COVER: Komatsu

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IM uses, as preference, SI units throughout, so, for example, all tonnes are metric unless otherwise stated. All dollars are US unless otherwise stated

Antamina moves ahead

On February 15, 2024, Peru's National Environmental Certification Service for Sustainable Investments (SENACE) approved, after a detailed evaluation process, the Modification of the Environmental Impact Study (MEIA) of copper and zinc mining major Compañía Minera Antamina. This approval allows for an investment of approximately US$2 billion over the next few years, following Antamina's internal governance process, which will allow the company to extend its operations from 2028 to 2036 in the Áncash region.

The MEIA will allow Antamina to optimise existing mining components within its current operation, underpinning environmental, social and operational sustainability. Among the main modifications are the expansion of the footprint of the open pit, and the expansion and optimisation of the dumps and tailings dam. These modifications have been designed under strict engineering protocols, which guarantee safe conditions for workers and adjacent communities.

As these are changes within the area of operations, the positive relationship that the company has managed to consolidate for more than 20 years with neighbouring communities and populations it says will remain unchanged. The MEIA has been the result of rigorous technical work that involved various state entities and top-level consultants. During the evaluation stage, three citizen participation processes were carried out between 2019 and 2022 in the area of social and environmental influence, incorporating cultural and diversity aspects. This made it possible to integrate valuable contributions from the public sector, communal authorities and citizens.

Víctor Gobitz, President and CEO of Antamina, thanked all parties involved in this process. "The MEIA is an important milestone for Antamina and the Peruvian mining industry, and reaffirms our commitment to the country and the Ancash region. This approval broadens our horizon and allows us to continue working hand in hand with the authorities and communities to deploy a mature public and private institutional framework, which seeks to transform economic resources from mining into sustainable development for all," he commented.

Antamina is one of the leading copper producing companies in Peru, and one of the largest in the world; Its shareholders are BHP, Glencore, Teck and Mitsubishi. In terms of the consultants Antamina has worked with, DRA has played an important role. Back in 2020 it was elected by Antamina to lead the Early Contractor Involvement (ECI) phase of the Waste 1 project and has continued working with Antamina on various projects since then including involvement with the Waste 2 and CCS elements of the MEIA. Stantec has also provided extensive tailings-related services to Antamina as well as preparation of the MEIA document itself.

The MEIA outlines the changes at Antamina going forward. The mine area will be increased by 25% and the open pit will be deepened by additional 150 m will be deepened. Up to 173,000 t/d of ore will be extracted, with a waste movement of up to approximately 742,000 t/d.

There will be replacement of the primary ore crushing station and installation of a new Waste 2 rock crusher. Two new tunnels will be built along with associated conveyor belts: one for ore towards the processing plant and the other (Waste 2) for waste towards a spreader at the waste dumps. The conveyor belt system will complement transportation by mining trucks, which will remain at the current levels. The Waste 1 part of the project involves optimisation of the existing waste crushing and transportation system to the waste dumps.

Specifically, the ore extracted from the pit will be taken to the crushing and ore transportation system (also called the CCS). This auxiliary facility will have modifications that will consist of the inclusion of the new primary crushing station, which will be inside a buried concrete building, and the belt hauling system that will transport and unload the ore through stackers fixed to the processing plant storage piles.

There will be a 26% increase in waste storage capacity at the Este waste dump to reach 3,840 Mt and a 32% increase at the Tucush waste dump to reach a capacity of approximately 1,280 Mt. Este's footprint will increase by 36% to reach an approximate surface area of 1,494 ha. The optimised design for Tucush will generate an increase in the footprint by 8% to reach a total surface area of 346 ha.

At the tailings dam, 195 m will be added at the base and 30 m in height, applying a design that guarantees the safety of the infrastructure. This increases the approved elevation of 4,165 m above sea level to the elevation of 4,195 meters above sea level. The dam will reach a storage capacity of approximately 1,527 Mt from the current 1,100 Mt and the footprint will occupy an area of approximately 905 ha.

Antamina will also optimise some equipment and processes in the processing plant in the main stages of crushing, grinding, classification and flotation, to reach a capacity of 208,000 t per day and maintain the annual production volume, through the replacement, modification and/or addition of equipment in seven areas.

Paul Moore
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The Electric Mine 2024, in Perth, Western Australia, will host over 800 attendees for three days of presentations, panel discussions and networking. A selection of high-profile speakers already confirmed include:

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Rio Tinto

Lucca Machado
U&M

Jonas Ranggård
Boliden

Peter Wan
Teck Resources

Geoff Devin
Rio Tinto

Jason Bowsher
Freeport McMoRan

Dave Rawlins
Fortescue

Shane Clark
Thiess

Meheroop Chopra
Fortescue

Paul Lucey
Worley

Greg Bell
RUC Mining

Pieter Doelman
OceanaGold

Andrew Scott
BHP on behalf of GMG

Chris Carr
IGO Limited

Scott Williamson
Blackstone Minerals

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Gekko brings real-time grade measurement to the gold sector

Gekko has launched "Mark 3" of its online gold analyser, OLGA, the flagship product for the company's real-time data instrumentation division, which operates alongside other key products such as the Carbon Scout to assist in measuring the recovery of gold real-time in gold processing plants, Nigel Grigg, General Manager – Global Sales & Solutions, Gekko Systems, says.

"We are really excited about these new design elements which will improve value and returns for our clients as well as improve ease of operation," he said. "Now gold grades can be measured in real time compared with the traditional assay-based process which can often result in two-day delays. Operating management will be able to respond immediately if there is a gold excursion or if the data provides other insights into plant trends. This is a breakthrough technology which is now even more affordable and will deliver higher yields in processing plants."

The OLGA has at its heart the world-first proprietary "Golden Eye" lens technology developed and designed in Australia's government-funded CSIRO research laboratories. This component measures gold grade in slurries and solutions combined including low grade slurry streams down to as low 0.1 parts per million. Other elements are also measured including copper, silver, platinum and nickel. The multiplexing feature will allow for up to four streams within a processing plant to be assessed for gold grades, according to Gekko.

The OLGA is the only real-time online measurement system purpose built for gold, Gekko claims. The unit is typically installed to measure the cyclone overflow stream in CIL leach circuits, around the electrowinning circuit and on flotation feed, tails and concentrate. With the multiplexing function, the OLGA can switch measurement of grade from stream to stream.

"The technology represents a significant step forward in the potential to automate gold leaching circuits," Grigg says. Another key feature of OLGA is the dedicated sample feed line, facilitating continuous sampling of large volumes with no potential for cross-contamination. The system also offers additional sample points for ad-hoc samples, providing flexibility and adaptability to changing operational needs. Furthermore, the ad-hoc samples can be analysed as batch samples, minimising sampling errors and substituting the need for other sampling systems.

The OLGA Mk3 has undergone rigorous testing and refinement to ensure its robustness, reliability and accuracy in various operational conditions, while offering low maintenance requirements, Gekko says.

Gekko says OLGA's development was supported by collaboration partners who assisted and provided critical feedback to improve an earlier OLGA technology design. That collaboration included the management and technical teams at Gold Fields, CSIRO, Orway IQ, Curtin University, METS Ignited and Gekko Systems.

Core to the assessment was an OLGA installation at Gruyere Gold Mine (a JV between Gold Fields and Gold Road Resources) where the OLGA achieved excellent results indicating a strong correlation between the automated OLGA and manual assay data and giving the Gekko team the confidence to further develop the OLGA, Gekko concluded. **https://www.gekkos.com**

Elphinstone launches new E15 hard rock support vehicle

Elphinstone has introduced its new E15 model to the Elphinstone Underground Hard Rock Support Vehicle range. The low-profile E15 it says is a welcome addition to the existing range of E10 (formerly WR810) support vehicles, with both base platforms sharing a high level of interchangeability of parts and components.

The significance of the model number is the letter 'E' represents Elphinstone, and the numeral '15' indicates the nominal capacity in metric tonnes (depending on the configuration).

The first machines to be released include the E15 Agitator 7m³ (pictured), E15 Delivery (nominal 15 t capacity and 8.8 tm crane), E15 Flat Deck (nominal 16 t capacity), E15 Water Tank (nominal 13,000 L capacity), and E15 Fuel & Lube (diesel, lubricants, grease, coolant, DEF, water & air). Additional models will be released in the future.

Headlining the E15 series is the Agitator 7 m3, built to thrive in harsh underground hard rock mining conditions, providing outstanding ride and handling with excellent manoeuvrability and turning circle, says Elphinstone. At 2.4 m high, the front-mounted operator cabin features three-person seating, climate-controlled air conditioning, ergonomic central driving position with a clear 180-degree view, and dial controller for the retarder, speed and implement controls. Operator comfort and convenience is further enhanced with an air-cooled compartment for lunch box storage, cupholders and smartphone charging ports.

The combination of the A-frame front axle suspension, oscillating hitch and air-suspended seats, deliver a high level of machine comfort to the operator and passengers. The oscillating hitch ensures 4-wheel ground contact and reduced wear on the hitch and steering components. Nitrogen charged hydraulic suspension cylinders and A-frame provide superior front axle ride quality over rough terrain.

Common to both the E15 and E10 range, the engine front frame can accommodate optional Cat C7.1 Tier 3 or Tier 4 Final engine arrangements featuring Caterpillar's breakthrough ACERT™ Technology to meet exhaust emission reduction standards.

The engine's efficient fuel delivery combined with air management and electronic control lead to high productivity and exceptional service life. An optional full-flow DPF may be fitted in place of the standard muffler and catalytic converter on Tier 3 models.

All engine and machine isolation functions are conveniently located on one panel accessible from ground level on the left-hand side. All service points such as tanks, filters, lubrication points and compartment drains are conveniently located at ground level for servicing.

The monitoring system and alarm strategy provides a 3-tier warning and shutdown functionality alerting the operator of any abnormalities and automatically limits the machine's functions. Onboard advanced machine diagnostics provide the operator and maintenance staff valuable information which simplifies machine servicing. All the application modules pin and or bolt to the common rear frame, including the 7 m³ agitator bowl. With 16.00 R20 tyres, heavy-duty axles and different weight distribution, the machine has greater carrying capacity.

An optional feature of the E15 are the front and ▶

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rear hydraulic jacks. The front jacks operate with a 'park' function to enable the operator to safely exit the cabin with the engine operating. The rear jacks are used to level or lift the machine for discharge. All jacks can lift the machine off the ground for changing tyres.Fitted as standard to the rear frame is a high-capacity electromagnetic retarder which provides superior braking performance on grade, and diagnostic capabilities with alarm and fault conditions reported back to the 12-in touch screen operator display.

The integrated Retarder Control System (iRCS) combines both the control and power functions into a single unit. The innovative electronic design significantly reduces the retarder's energy consumption, preserving electric circuits.

The E15 also features 'speed control' whereby the operator can set the maximum speed on grade and the machine uses the retarder and the inertia of the powertrain to maintain the speed. When on flat ground the operator can accelerate over the maximum set speed, but when the accelerator pedal is released, the machine speed will revert back to the original maximum speed setting.

Downtime during service and maintenance is reduced markedly on the E15 due to clever engineering and design features, incorporated

with service personnel in mind.

Quick change air filters and 500-hour oil service intervals reduce downtime and keep machines in operation longer for greater productivity. A centralised onboard service centre includes fast fill, evacuation, and fluid sample points for analysis.

The 24 V electrical system features colour-coded wiring circuits with individual circuit breakers. The wiring is sealed to prevent dirt and moisture and enveloped in fire-resistant material. The onboard diagnostic system checks all critical machine functions for faults, with all data recorded for analysis.

Operator safety is a high priority in mining machine operations. Integrated into the E15 and E10 operator station is an ISO 3471:2008 standard ROPS and ISO 3449:2005 standard FOPS that offers protection to the operator.

Other safety features include fuel water separators made of non-flammable material, firewalls and heatshields, machine interlocks, centralised isolation points (engine disconnect switch, starter isolation switch, jump-start receptacle and fire system activation, if fitted), and an optional integrated fire suppression system.

As an authorised Caterpillar OEM, all machine sales, technical assistance and access to spare parts are available and supported through Elphinstone and the global Cat dealer network. **https://elphinstone.com**

Metso announces major comminution equipment order for De Grey's Hemi

Australian mining company De Grey Mining Ltd has awarded Metso orders for a Superior™ MKIII 50-65 primary gyratory crusher and two 14 MW Premier™ ball mills. The equipment will be installed at De Grey Mining's Hemi Gold Project located in the Pilbara region of Western Australia. The combined order value of over ¤20 million is booked in the Minerals segment's first-quarter 2024 orders received.

"Our aim with the Hemi Gold Project is to deliver a Tier 1 gold project and make a future top five Australian gold mine from a production perspective. The 10+ Mtpa process circuit will be equipped with state-of-the-art equipment and proven technologies contributing to responsible ore processing. We've just partnered with Metso in delivering the first key items for the process circuit, namely the primary gyratory and ball mills, and we're looking to make the rest of the process equipment decisions soon. De Grey will make a series of payments according to milestones achieved over the manufacturing period and final commissioning, typical for contracts of this nature, commencing in March 2024," says Glenn Jardine, Managing Director of De Grey Mining.

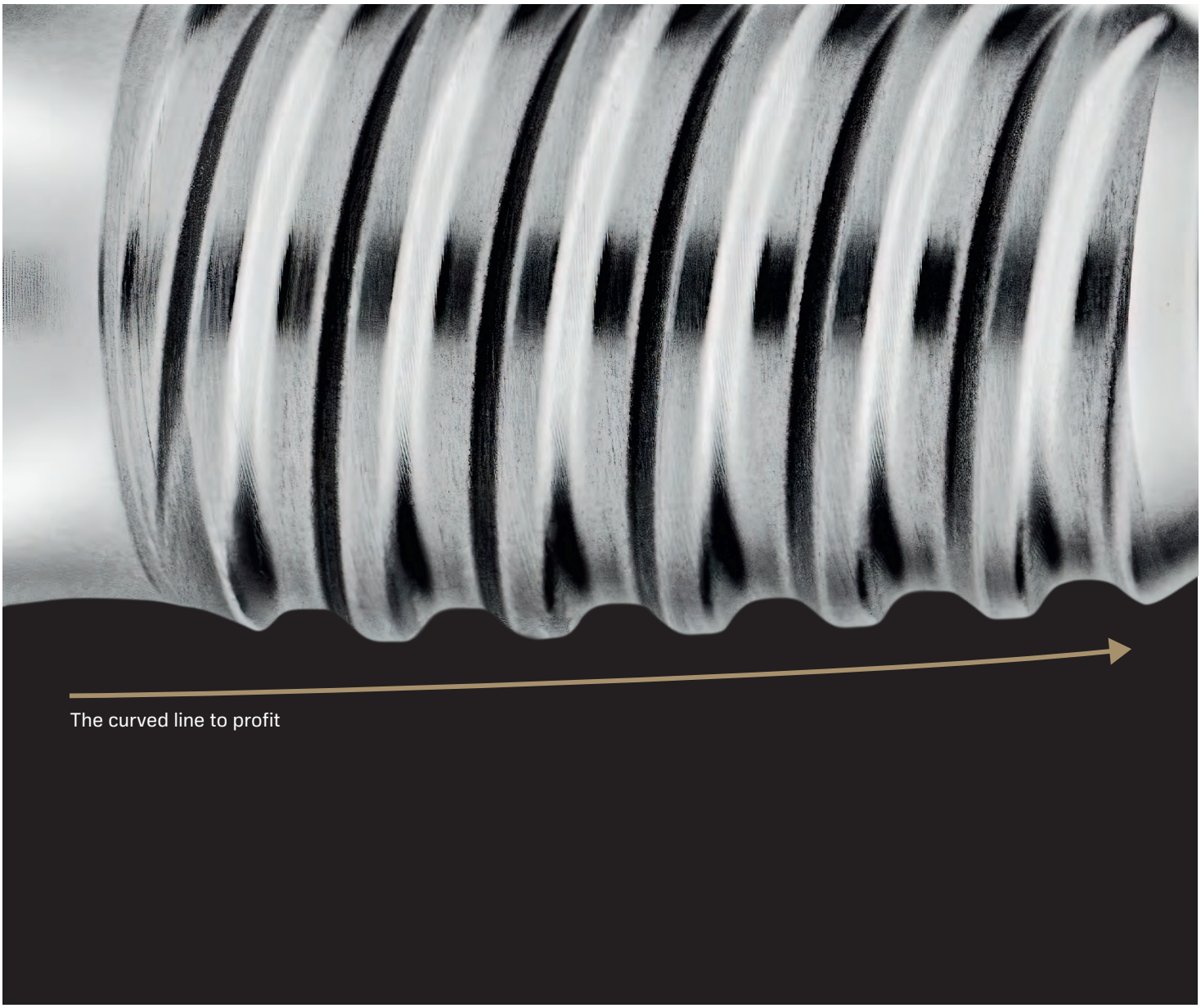
"Metso's third generation Superior™ MKIII primary gyratory crusher, renowned for its safe and efficient operation, will be the driving force

for Hemi Gold's entire processing circuit, and the two Premier™ ball mills will provide optimized grinding performance and the highest availability for the concentrator. Both mills are equipped with failsafe Metso Polymer Hydrostatic Shoe Bearing (HSB) systems, significantly increasing reliability and reducing maintenance costs," says Kai Rönnberg, Vice President, Minerals, Asia Pacific at Metso.

"We look forward to working on this project and future ones with De Grey Mining. In terms of servicing our customers when plants are operational, Metso also has an extensive footprint in Australia. Our state-of-the-art Karratha Service Centre in the Pilbara, which will be Metso's largest Service Centre globally, opens this March. The Karratha Service Centre will be able to support our customers, as well as the Hemi plant, with the latest technologies and sustainable aftermarket solutions," concludes Rönnberg.

The Metso Superior™ MKIII primary gyratory crushers Metso says provide high throughput and less downtime, enabling maximum efficiency for the operation. "The product family has been developed especially to meet the needs of customers with changing ore grades and conditions in mining operations. Metso also provides a comprehensive scope of spare and wear parts and services to optimise the crushing circuit operation throughout the lifecycle." Since the product family's launch in 2018, Metso has sold more than 50 Superior™ MKIII primary gyratory crushers around the world.

For horizontal grinding mills, Metso says it offers the industry's widest selection, including the Planet Positive Metso Premier™ and Select™ mills. The energy-efficient mills can be easily integrated with Metso mill relining equipment and are supported by an extensive services network to ensure optimisation during the mills' lifetime. Metso also says it offers the market's most comprehensive mill linings range and relining services, with materials and designs optimised for each application. **www.metso.com**



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Pre-concentration: it's worth asking the question

We've reviewed a novel, vendor-agnostic pre-concentration screening test in part one and explained a comprehensive five-step pre-concentration evaluation in part two...now for part three in the three-part series with SRK Consulting (Canada) Inc's Adrian Dance (Principal Metallurgist) and Bob McCarthy (Principal Consultant)

SRK Consulting's Adrian Dance and Bob McCarthy have devoted years to ensuring the mining industry can make informed decisions about pre-concentration within their flowsheets and are now able to screen the opportunities quickly, cost-effectively and without vendor prejudice.

"We have been carrying out the different parts of the five-step evaluation process over the years, refining them independently and sometimes together," McCarthy tells ***IM***. "It is only now that we can present them all in a holistic way."

This five-step process – which includes heterogeneity analyses; "size the prize" economics; laboratory test work that involves X-ray Transmission (XRT) based sensor technology; mine planning; and mine economics – has been deliberately designed to allow mining companies to pause at the end of each phase to re-evaluate if there is a strong enough case to continue with a pre-concentration investigation.

The importance of such an approach has grown in recent years as more projects that are "grade-challenged" or metallurgically complex are being considered for exploitation by mining companies as the demand for metal increases worldwide.

Sensing this (pun intended), sorting and sensing manufacturers have been on the mining charm offensive, proclaiming the benefits of their technology – benefits that include cost reductions, improved metallurgical recoveries, rationalised use of energy and water, and more.

These market dynamics have created a void that SRK is looking to fill by providing the tools for both sides to assess the options and carry out informed decision making on which routes to pursue.

"We were concerned that the manufacturers didn't have the background needed to understand the mining industry's requirements," Dance said. "At the same time, mining companies had difficult projects and deposits where they saw pre-concentration potential but didn't know where to initially go to explore that potential.

"We saw a space for industry representatives like ourselves at SRK to bridge that divide."

The independent testing that SRK has been able to offer for the last six or so months through its partnership with Base Metallurgical Labs (BML) in British Columbia was the final piece of the puzzle in establishing this now-established five-step process.

Able to not only indicate pre-concentration amenability but also provide key inputs into the pre-concentration strategy selection and evaluation, this has been employed for some 36 samples (close to 2,000 particles) being tested using the XRT unit situated in BML's facility in Western Canada.

Demystifying the tech

While this XRT testing may have only recently become available to SRK and BML customers, the outcomes of SRK's pre-concentration evaluation have been described to investors and stakeholders trawling through NI 43-101 reports up to the prefeasibility study (PFS) level for some time now. Various parts of the five-step evaluation have come into sections on metallurgical test work, mineral reserves, mining methods, costs and economics.

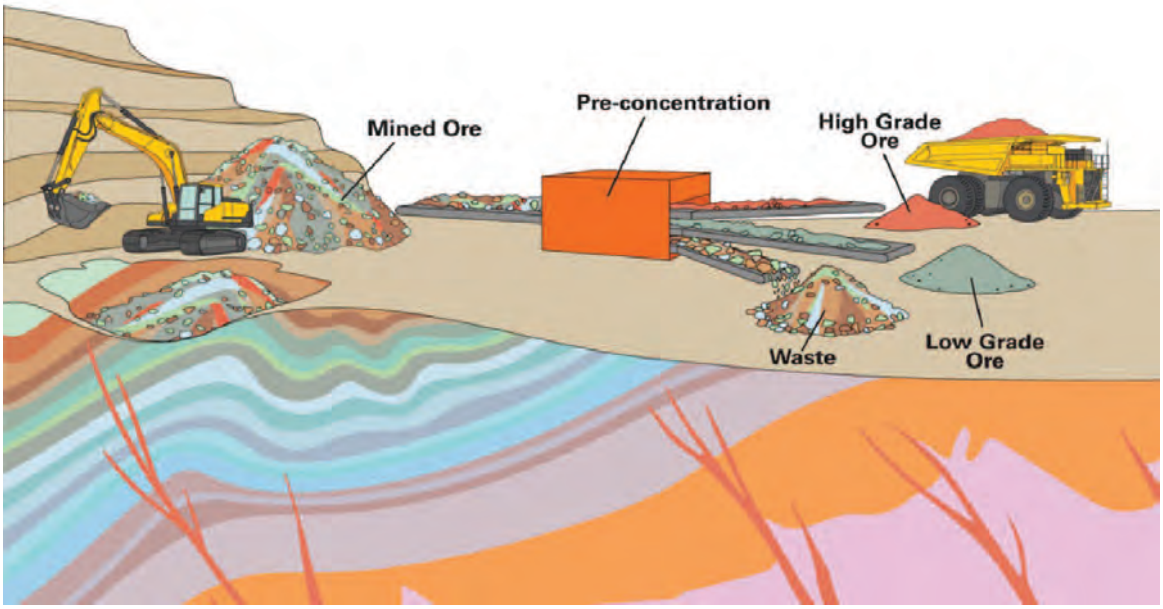
"Where the results feature is tied to what study stage the company is at and where people feel comfortable with pre-concentration," McCarthy explains.

Providing comfort to mining companies and their investors is always difficult when examining any new flowsheet addition, hence the reason why many companies are initially pursuing pre-concentration or ore sorting in a 'recovering ore out of waste' scenario from material already deemed to be waste and having no economic value.

As a result, SRK has been very deliberate in the protocols it is pursuing.

Dance explains: "Because there is still a perceived 'magical' nature to pre-concentration in that it can provide reserve upgrades and higher recoveries, we need to do more detailed evaluations at a preliminary economic assessment or PFS level than would be expected for other types of processing technology."

For instance, the company is currently engaged on a gold operation where it has tested upwards of 22 samples (1,320 particles) for validation. "At this level of study, if you were working on comminution or leaching, the same process validation would be carried out with two or three tests," Dance said.



Various parts of SRK's five-step evaluation are referenced throughout sections of 43-101 reports on metallurgical test work, mineral reserves, mining methods, costs and economics

"In no way are we competing with vendors – we are not suggesting we have the expertise they have," Adrian Dance says. "Rather, we are looking at the characteristics and amenability elements for the vendors to then truly apply their expertise, knowledge and sensor selection understanding"

McCarthy added: "We firmly believe that this five-step evaluation will allow people to sign off, at least at a PFS level, on whether pre-concentration is a viable route for them to take. Our process will prove this through testing and pulling different economic levers in the economic evaluation to quickly see where the value is, and where it isn't.

"If pre-concentration is viable, you would then likely see clients moving on to performance testing with some of the sensing/sorting vendors at the feasibility study stage."

Welcoming the independence

Those who understand the pre-concentration space have welcomed the involvement of SRK through its five-step process and, in particular, have highlighted the industry need for standardised and independent testing.

"They see where we are inserting ourselves into stages of the client and vendor relationship," Dance said. "In no way are we competing with vendors – we are not suggesting we have the expertise they have. Rather, we are looking at the characteristics and amenability elements for the vendors to then truly apply their expertise, knowledge and sensor selection understanding."

At the same time, Dance and McCarthy are looking to arm mining companies with relevant knowledge about pre-concentration principles, where the process could provide a grade uplift and what losses might be associated with the implementation. This is being done through gaining a better understand of their orebody through the testing.

It should result in mining companies providing a more representative sample to the pre-concentration vendors for the performance testing many of them offer. "Mining companies can then understand these pilot test results more broadly and ask more questions, if needed," Dance said. At the same time, the vendors have a 'pre-qualification' check in hand: they would know from the SRK process if there is a strong basis for carrying out the performance test in the first place.

And, of course, SRK can get involved after the five steps are complete, carrying out small-scale work and integrating these results with the larger scale performance testing that could eventually underpin a flowsheet developed by a third-party engineering company.

"We view pre-concentration as another aspect of geometallurgy that needs to be interrogated just like comminution and flotation," Dance said.

The future focus

It is potential changes to both of those processes that could have positive implications for pre-concentration in the mining sector.

"We're now seeing more flowsheets designed with a multi-stage comminution flowsheet that, at every stage, asks: 'do I need to process the oversize material again?'" Dance said. "There is an opportunity for the right sensors to answer those questions. That is being highlighted in the design of some of this technology; some newer ore sorting units are reminiscent of cone crushers in size and shape, which means they can be inserted into this flowsheet with ease."

"We firmly believe that this five-step evaluation will allow people to sign off, at least at a PFS level, on whether pre-concentration is a viable route for them to take," Bob McCarthy says

And, of course, some pre-concentration-focused companies have gone upstream of the plant to the pit to provide these readings: an area Dance sees as representing the future.

"Heterogeneity is better preserved the further upstream of the plant you go, so it is obvious to think that pre-concentration technology – which feeds off this heterogeneity – should be placed here," he said. "The issue comes with getting a representative sample to test – whether that is a shovel load, or the equivalent of what a 200-t payload truck can carry. Ultimately the mining industry is at a 'prove it' stage when it comes to pre-concentration technology. The mining companies want to see results on paper or on a screen before they sign off on this technology and process. At the scale of a truck or shovel, this is very challenging."

McCarthy added: "The Heterogeneity and Scale analysis we are doing in step one of the evaluation will identify some of these opportunities within the selective mining unit sizing, but it is still early days on factoring that into sorting at a truck or bucket scale."

This work will require closer examination of the drill core than the typical 1-m assayed intervals, as well as a way to estimate the level of mixing that occurs between vertical blast holes, post-blasting, post-loading and post-conveying.

This comprehensive plan is broadening too, factoring in more than just economics.

For instance, SRK has made a case for carrying out the same sizing and XRT analysis included in the five-step evaluation for mill pebbles – which can represent up to 30% of the entire plant feed in some cases – to assess their true value.

This obviously has a cost benefit, as well as an energy benefit – avoiding recirculation of pebbles avoids excess energy use. This same testing is indicating there could be further energy benefits to be had by using pre-concentration, too.

In addition, "We have recently expanded our testing protocol to now measure specific energy requirements of the concentrated material compared with the original feed," Dance said. "This has shown (at times) a softening effect of pre-concentration that can produce measurable savings in power."

And the impacts on water and energy use are another avenue that could come into the 'size the prize' economics McCarthy uses in step two of the five-step evaluation process. "There is no reason to think this could not be included in the analysis in the future; all we would need are the metrics for the existing proposed operation – the amount of water and energy used for the number of tonnes in the mill feed," he said. "It will then just be a simple case of amending the two inputs based on the pre-concentration work."

Against a backdrop of falling grades, increasing metallurgical complexity and perceived future demand for commodities, the pre-concentration question needs to be asked by all companies. IM

FLSmidth's pyro-processing technology includes a two-stage cyclone preheater, a rotary kiln and an indirect rotary cooler, a natural gas-fired rotary kiln burner and a complete off-gas handling circuit

A recipe for success

The electrification drive has seen OEMs, service suppliers and innovators dive into the lithium space looking to gain share of a market expected to rapidly expand, Dan Gleeson reports

Taking today's price to one side, it is clear there will have to be a significant uptick in lithium supply for the world to fulfil the demand associated with its electrification ambitions.

Whether it is batteries in automotives, mining vehicles or energy storage, lithium has a significant role to play across many industries looking to wean themselves off fossil fuels.

There is no shortage of lithium available currently, but there are fears the conventional routes to extract it – solar evaporation in brines, for instance – will mean supply cannot keep up with projected demand. At the same time, such routes are typically both water- and energy-intensive: two attributes companies mining the material do not want to be associated with in today's growing 'green' economy.

IM delves into some of the avenues companies are considering as part of their current and future lithium processing plans.

OEM solutions

Unsurprisingly many of the big original equipment manufacturers in the mining space have been working on solutions to tackle the challenges mining companies are facing, realising this is a market that they could get lots of business from.

Metso, for instance, looks to cover the complete lithium value chain, offering spodumene-focused solutions that could result in a lithium hydroxide product, or brine-focused options for eventual lithium carbonate output.

Mikko Rantaharju, Head of Hydrometallurgy at Metso, explained on the company's battery metals offering: "We have a comprehensive offering from mine pit up to battery-grade metal salts, including process development, testing services, equipment and aftermarket services, all aimed at supporting our customers to meet their targets."

This is complemented by a digital offering that includes the Sense series products and the Geminex™ digital twin; the former represented by intelligent instruments that monitor the various processes in the plant and the latter allowing mining companies to plan and test out the interactions between different stages of processing in a simulated environment to come to the optimal outcome.

This end-to-end portfolio – which Metso says is the industry's only holistic battery metals offering – enables the company to optimise the processes across all these areas.

Avalon Advanced Materials Inc is looking to tap into this knowledge, having recently signed a memorandum of understanding to create a strategic partnership with Metso aimed at establishing terms to develop a lithium hydroxide production facility to process lithium mineral concentrates.

Avalon intends to deploy Metso's technology – including its advanced alkaline leach technology – to construct and operationalise a full-service lithium processing facility at the company's recently acquired Thunder Bay site in Ontario.

Upon completion of the project, Avalon says it will be the first vertically integrated lithium producer in Ontario, while ensuring Canada's electric vehicle battery manufacturing base has a stable, proximate and long-term supply of this resource.

The non-binding MoU was recently converted into an expanded partnership agreement to advance the construction of a full-service lithium processing facility in Thunder Bay. The parties also agreed to co-develop a Technology & Innovation Centre to be located on-site in Thunder Bay, accelerating an Industrial Park concept that will co-locate key supply chain partners.

This will see:

- Metso provide testing and engineering equipment procurement and related services to develop and commercialise Avalon's Thunder Bay lithium processing facility;
- The creation of a testing laboratory for research and development on lithium and clean technology solutions; and
- Avalon and Metso to cooperate on the recycling of used batteries and the refining of battery chemicals for recycle use.

Through the R&D efforts undertaken by Avalon and Metso, the proprietary lithium hydroxide process the companies are looking to leverage represents a far more sustainable conversion method compared with conventional acid roasting, Avalon says. The process operates in an alkaline state and uses pressure leaching, which is unique for lithium conversion, eliminating the use of sulphuric acid, and with no production of sodium sulphate as a by-product.

Instead, a substance called analcime – an inert solid aluminium silicate – is produced, as well as calcium carbonate. Importantly, both substances have commercial uses in industrial building applications and other industries. The method also reduces overall air emissions compared with conventional lithium processing, according to Avalon.

FLSmidth, meanwhile, has been garnering interest for its own advanced calcining system to support critical functions in the lithium hydroxide space.

Such pyro-processing technology has been within the FLSmidth offering for some time, but, with lithium demand on the up, mining and downstream companies are looking to leverage it more.

Sibanye-Stillwater's subsidiary company, Keliber, recently entered into an agreement for the supply of pyro-processing technology to the Keliber project's lithium hydroxide refinery in Kokkola, Finland. The agreement built on an existing relationship involving testing and engineering for the Kokkola lithium hydroxide refinery.

The pact will see FLSmidth deliver the advanced calcining system that will support

critical functions in the overall processes in the refinery. The pyro-processing technology includes a two-stage cyclone preheater, a rotary kiln and an indirect rotary cooler, a natural gas-fired rotary kiln burner and a complete off-gas handling circuit. The two-stage preheater rotary kiln represents the state-of-the-art system for facilitating spodumene phase conversion for maximum lithium recovery, while minimising fuel consumption, FLSmidth says.

The Keliber project has previously piloted FLSmidth's technology using Keliber's own spodumene concentrate. Sami Heikkinen, Site Manager of the future Keliber lithium hydroxide refinery, said: "We have seen excellent test results, indicating that the FLSmidth technology has the potential to deliver the required output in an energy-efficient way."

The planned annual production from the refinery is expected to be 15,000 t of lithium hydroxide monohydrate and is expected to be one of the first integrated operations in Europe to sustainably produce battery-grade lithium hydroxide using its own ore.

Calix's patented calcination tech

Speaking of calcination technology, **Calix** recently executed a joint venture agreement with Pilbara Minerals for the development of a demonstration plant using Calix's patented technology at the Pilgangoora project in Western Australia.

The objective of the "Mid-Stream Demonstration Plant Project" is to deliver a superior value-added lithium product enabling lower product cost, reduced carbon energy intensity and reduction of waste product logistics.

A successful demonstration of the calcination technology via this plant may then lead to its commercialisation with the JV licensing the technology to the global spodumene processing industry, Pilbara Minerals says.

TOMRA overcomes contamination challenges

Sensor-based sorting can help lithium mining operations unlock untapped potential and meet the rising needs of the market, according to **TOMRA Mining**.

The main challenge in hard-rock lithium mining comes from basalt contamination, TOMRA says. This high-iron, barren material has a high density very similar to that of spodumene. It means that when dense media separation (DMS) is used as the primary spodumene concentration process, basalt is concentrated with spodumene, contaminating the final product.

"This issue can be addressed by selectively mining high-grade ore, but contamination is unavoidable, and this approach ultimately results in a sub-standard product unsuitable for sale at market rates," the company says. "This contaminated product is usually stockpiled, leaving valuable lithium resources unexploited. The DMS and crushing circuits utilised to produce lithium concentrate from ore are extremely energy-intensive and carrying contamination through the plant decreases productivity and increases costs."

The solution to this challenge lies in sensor-based sorting, according to TOMRA, with its technologies able to effectively remove basalt contamination before crushing, thus optimising the capacity of the processing plant, reducing energy consumption and waste, as well as lowering the environmental impact of the process.

"They (sensor-based sorters) allow mining operations to consistently achieve the required grade of the product and expand their resources to include more iron and basalt contaminated orebodies," it says.

TOMRA's sensor-based sorting offering relies on colour cameras, X-ray Transmission (XRT) sensors and multi-channel scanning lasers to sort the ore prior to the downstream wet processing. The sensors analyse particles, identifying the ore and waste in milliseconds, and directing particles at high speed to product or waste chutes via air jets. They can process material at a capacity up to 350 t/h in a single sorter.

These high-speed sensor solutions can sort a wide size range – from around 6-200 mm – to maximise the removal of iron and basalt from the

TOMRA has been awarded a contract to design the world's largest lithium sorting plant at the Pilgangoora lithium mine in Western Australia

feed. With these technologies, it is possible to minimise the unsorted fines that are discarded or stockpiled, and it has been extensively proven that they are effective in consistently reducing the contamination of the ore to less than 4%, according to TOMRA.

This was the experience of Galaxy Resources at its Mt. Cattlin Mine in Western Australia, where a TOMRA PRO Secondary Laser sorter has been in operation since 2021 to reduce basalt contamination in the pegmatite-hosted spodumene.

And, at the world's largest lithium sorting plant, TOMRA is set to overcome similar contamination challenges.

Working closely with Pilbara Minerals' metallurgical team, TOMRA conducted a geological assessment of sample ores supplied by the company. It revealed that the pegmatite deposit did have non-lithium bearing host rock intrusions. Some of these minerals have a high density like that of spodumene, which means it is also concentrated when using Heavy Media Separation. This reduces the efficiency of downstream flotation and contaminates the final product.

The ability of TOMRA's sensor-based sorting technologies to measure the colour, density and mineralogical variations in individual particles enables the accurate detection and removal of this barren material. This was proven out in test work for Pilbara Minerals and has since led to TOMRA being awarded a contract to design the world's largest lithium sorting plant at the Pilgangoora lithium mine in Western Australia.

A multi-sensor platform approach

STEINERT, too, sees the potential of sensor-based sorting technologies to overcome the processing challenges associated with hard-rock lithium mining.

Using STEINERT's multi-sensor platform approach provides flexible sorting solutions to decrease the carbon footprint of existing processing routes in a completely dry separation process, it says. Through a combination of XRT and laser sensors, the company can offer a single-step dry process to remove impurities such as iron oxides while increasing the lithium oxide content of the pre-concentrate.

In one example, testing at STEINERT's Perth test facility resulted in a 90% increase in lithium oxide content – to 1.67% Li_2O – and a 93% decrease in iron oxide – to 0.4% Fe_2O_3.

The director of the mining project in question said STEINERT's technology was the "perfect fit" for lithium, providing great control between ore and waste. He also believed ore sorting technology would provide greater operational flexibility within the mining operation, while increasing head grade to the mill.

Water wins

BQE Water specialises in providing innovative wastewater treatment solutions to the global mining industry

From holistic water management approaches to dewatering pumps and technologies to water treatment including a specific focus on selenium, Paul Moore takes in a bit of everything in this water in mining focus

Looking at water management in mining, it is good to look at the big picture and the overall approach. A holistic, multidisciplinary and integrated approach to water stewardship provides the most effective and defensible route to setting and achieving water saving targets, argues Grace Yungwirth, Technical Director – Mine Water at **WSP**.

She adds: "The equitable and sustainable use of water is one of the key challenges facing mining companies around the world, and one that touches upon many aspects of environmental, social and governance (ESG) performance. In areas of water scarcity, reliable and sustainable access to a suitable supply of water is critical, not just for mining companies but all local water users, whether for communities, agriculture, or other applications. Meanwhile, commitments to positively support local ecosystems and nature-positive outcomes place additional demands on water priorities."

Against this background, mining companies are committing to reduce their water consumption and improve their water recycling and reuse metrics. Yungwirth: "There is a business imperative here: reliable access to water of suitable quality is frequently identified as a key risk to the continuity of mining operations. But companies also recognise that water is an essential communal resource and are committed to its equitable and sustainable use by all of the catchment stakeholders."

This is a complex undertaking. Water stewardship investments must be balanced against financial costs and other objectives, such as decarbonisation, net zero and energy use targets. Yungwirth: "In addressing this challenge with WSP's mining clients, we have found the best solutions are developed through a holistic and collaborative approach. Forming a multidisciplinary team of technical experts, operational staff and project stakeholders, we brainstorm potential opportunities and are able to innovate solutions drawing on different areas of expertise. Identified opportunities can then be evaluated at a high level and developed through to concept level engineering and costing to allow evaluation of the options on a cost per megalitre saved basis, alongside other local and project-specific priorities."

She argues that a particular benefit of this multidisciplinary approach is seen when identifying potential technologies and solutions for delivering water savings. "Because these will encompass the integrated expertise of all stakeholders, the result is a more comprehensive assessment than could otherwise be achieved and that moves beyond the typical approach of interrogating the water balance. Results will certainly include technologies that are widely known, such as evaporative covers or dewatered tailings. But novel options will also rise to the surface, like replacement of pump gland seal water with mechanical seals, as seen in the oil and gas industry."

The ultimate outcome is a well-documented, defensible and inclusive plan for targeted investment in water stewardship programmes at the site or across a portfolio of sites. "This is an incredibly powerful tool for the operator, bringing transparency to decision making, with key stakeholders clearly able to see why certain projects are prioritised over others. These key decisions can then feed into both corporate target setting and reporting."

She concludes: "There is little doubt that mining and mineral processing operations will require an increasingly proactive approach to water stewardship, including a focused approach to water savings, to meet ESG targets and mitigate water-related risks. We have seen the benefit of close collaboration between a mining company's technical teams, multidisciplinary consultancy teams, and engagement with all relevant stakeholders, to develop a comprehensive and integrated assessment of solutions. Such an approach offers the potential to expedite the mining industry's ability to meet their ESG commitments while promoting transparency and trust with stakeholders, advancing water stewardship priorities, and of course saving water."

Optimal results and operational flexibility in underground dewatering

Underground water management in mining can be challenging. Looking at this topic we talked to Nick Lancaster, **Weir Minerals**, Product Manager – Mine Water, Thickened Tailings and Paste Pumps. He says that in the past, the majority of underground mine dewatering systems were clean water systems, requiring large sumps to settle out solids. "However, there's now more of a focus on quicker implementation of dewatering systems and an understanding among mine operators that mine water is never really clean – that it always has some solids in it and that needs to be planned for."

As a result, underground mine dewatering systems are increasingly being designed to handle dirty water from the outset. Lancaster says this might mean using more robust materials within a clean water pump or simply designing a pumping system that's capable of handling dirty water.

This latter option has advantages in terms of space and capital expenditure. "Put simply, there are obviously space constraints in underground mines and if the pumping system requires additional space to be excavated for settling sumps or vertical dams, these works are both capital and time intensive. Moreover, dirty water pumps have been specifically designed for higher wear and abrasive duties."

Another common issue Lancaster says is that the sumps are almost always neglected and are rarely cleaned as frequently as they need to be, if

Warman® DWU 75 single-stage high-pressure pump, ensuring uninterrupted mining production in an underground operation

at all, to maintain proper settling to produce clean water. "As a result, the clean water pumps end up pumping dirty water before long and, inevitably, wear the pumps out much faster than originally anticipated. This then leads to unplanned downtime and increased operating costs, as well as the need to carry higher inventory to, in a sense, plan around the unplanned downtime."

Furthermore, the settling solids – which is essentially a waste product – has to be brought to the surface; this is typically done via the production skip, which is an inefficient system that's more energy intensive and less sustainable than pumping the solids to the surface.

He continues: "Mine operators want to focus their resources on driving production. Maintaining settling sumps means resources need to be reallocated away from production to keep the clean water pumping system operating reliably. Therefore, this loss of production cost needs to also be considered when choosing the type of dewatering system. Since most operations have already mined the easily accessible ore, existing mines are now going deeper to access the ore bodies. And ore bodies that were once too deep or too expensive to access are today's greenfield or brownfield expansion projects. This means that underground dewatering systems typically require higher pressures than they did previously."

Weir Minerals' Warman® DWU pump is able to handle dirty water with 10% w/w solids concentration, with high peaks during temporary upset conditions up to 20% w/w concentration. It is designed with a casing pressure rated at 700 kPa (1,000 psi), which means it's well suited to these high pressure underground dewatering applications. At maximum operating speed, the Warman® DWU pumps can individually achieve heads of approximately 140 m at the best efficiency point. However, due to the high casing pressure design, and when combined with the correct pump sealing selection, the pumps can be configured in an in-series solution to achieve discharge pressures of up to 55 bar.

Weir says it has multiple pump sizes within its Warman® DWU range to deliver various flowrates based on the site's requirements, from low flow for drier mines to very high capacity in wetter mines. "The ability to pump higher heads per pump, while also delivering higher casing pressure, means Weir can produce a higher total discharge than its competitors. Moreover, it typically needs less pumps in a series to achieve the same discharge pressure. As a result, the overall footprint is smaller, requiring less excavation. The reduced number of pumps reduces capital expenditure, while also lowering operating costs because there are less pumps to maintain and service."

As a mine gets deeper, Lancaster says that Weir has also developed a solution whereby its Warman® DWU pumping system can be mounted to a skid and dragged down the mine as it's progressively developed. "The system obviously needs to be able to handle the higher pressures required at greater depths. To ensure this, Weir utilises variable frequency drives (VFD), which allows it to simply speed up the pumps to match the required flowrate of the system as required."

The Warman® DWU pumps' casing pressure capabilities also provide additional flexibility. For instance, if an operator has a two-pump system and they want to go deeper, they can simply add a third or fourth pump to that system to achieve their head requirements. This also allows more traditional cascade pumping systems operating over many levels using a single pump per station to be optimised by combining pumps in series on a single level, thereby reducing the number of operating systems across many levels that need to be attended to and maintained.

One of the other challenges that many mines have to contend with are variable flows throughout the year, depending on climate. "For instance, in Canada, underground mines experience a lot of water ingress in spring when the snow melts and rains are higher. During these periods, it might be necessary to have two pumps running at a high flowrate and one on standby or, alternatively, it may be more effective to put them on a VFD to control the speed to ensure they're always operating near the best efficiency point."

Weir concludes that it partners with miners to develop, trial and implement dewatering solutions based on their unique operational requirements and their site-specific needs and challenges. "Planning for mine dewatering typically happens fairly early in the development of a new underground mine and there are a multitude of factors to consider. Weir has teams of experts and a portfolio of products that ensure it works with customers to provide the ideal solution based on their needs."

New approaches to tailings dewatering & valorisation

Clean TeQ Water recently established a partnership with mine tailings management company **Future Element** Pty Ltd. Future Element for its part recently joined Unearthed's Think and Act Differently (TAD) program, which is powered by BHP and allows innovators to engage in short experiments designed to de-risk ideas and fast-track technological breakthroughs. Future Element has joined the Essentials Minerals Cohort and will receive funding, mentoring, access to subject experts, and samples needed to undertake the testing.

Future Element, together with Clean TeQ Water, will be participating in a three-month program of testwork to prepare conceptual flowsheets, which can be applied to BHP's existing and future operations, for tailings dewatering based on the ATA® technology. The testwork aims to rapidly dewater slurries to produce dry stack tailings while making the critical minerals contained immediately available for recovery. The successful completion of the three-month program would lead to on-site piloting and eventual commercial-scale demonstrations.

The ATA technology was developed to offer a secure and low-cost mine tailings treatment process by rapidly separating water and solids to produce stackable dry tailings and recycled water. The technology uses smart chemistry to rapidly agglomerate the solids in ore slurries. The solids dewater under their own gravity, removing the need for high capital and operating cost pressurised filtration used in the industry today. The resulting materials can be compressed and stacked, with the extracted water being returned to the mine (or sent for recovery of dissolved metals), dramatically reducing water usage. In underground mining operations, the compact material may also be used for backfilling, with or without binder.

IM caught up with Brent Slattery, Future Element COO, for more insight: "Our mission at Future Element is to create a world without tailings dams; and help mining companies can deliver metals and minerals in a more sustainable way. There is a duality that comes with tailings in that they are expensive liabilities that often represent unacceptable levels of risk but also contain valuable minerals and water. We partner with mining companies to economically rehabilitate their tailings to unlock the value

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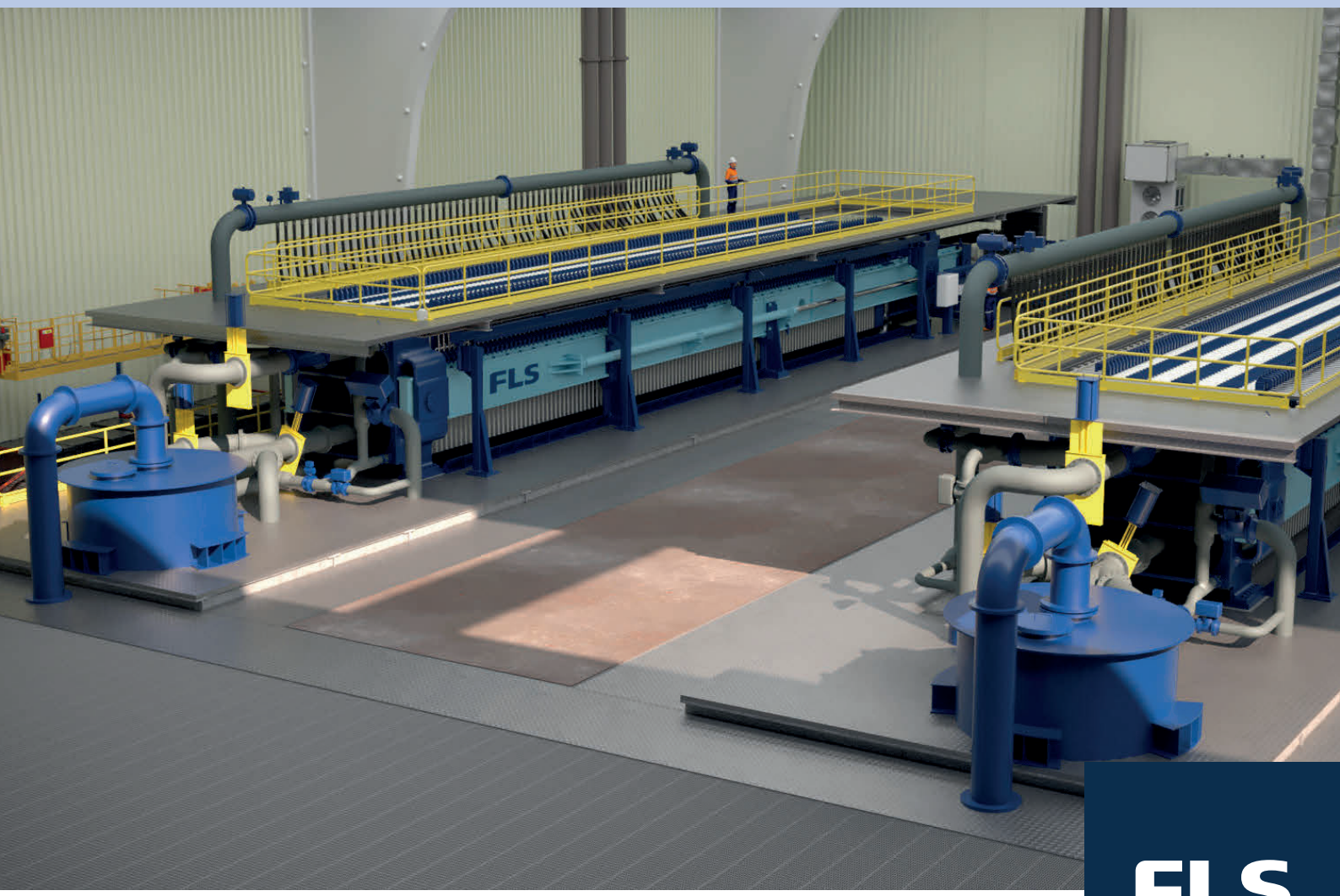

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that's stored inside, clean the water and restore the land. The relationship with CleanTeQ came about due to two Future Element partners – MD and CEO John Carr and Director Pat Walta – previously having worked there and therefore have good familiarity with its technologies. We really felt that some of those technologies can help unlock the value stored in tailings."

Slattery adds: "In addition to the ATA dewatering technology we like the CLEAN-IX technology for metal extraction which works well for recovery of metals in low concentration. That said, we are technology agnostic; we realise that every tailings dam is different with unique mineralogy – you are going to need a toolkit of different technologies to be able to solve these problems. The relationship with CleanTeQ is a good start, dewatering is a massive challenge and ATA is an amazing technology – the fact that it can dewater tailings under its own weight without mechanical compression is very interesting to clients – evidenced by the testwork program we recently announced relating to BHP. Once you dewater and move to a dry stack situation, I think that opens up a lot of different options around tailings valorisation – and removing wet tailings facilities."

On the BHP testwork, he adds: "We are focused on their South Australian copper business and will deliver a proof of concept for them with ATA, based on that will evaluate the commercial merits of a wider rollout. This work will be on existing tailings dam facility, but obviously, as new mines come online then you can design in dry stack tailings at the outset which means you aren't spending millions or billions in capital building or raising dams."

On its go-to-market approach, he says Future Element is engaging directly with mining companies on what it calls 'economic rehabilitation.' "This includes providing a service model to reprocess their current and historical tailings. We are developing partnerships with other technology and engineering firms but nothing I can disclose yet. Our main focus is bringing projects into operation, working with miners on joint ventures or using BOO/BOOT models where we reprocess the tailings for them for a fee. This helps them to eliminate wet dams and in the process, reduce closure costs, clean the water and ultimately return the land.

In terms of its depth of capability, Slattery also mentioned the team's collective experience from New Century Resources. "It was a major open pit lead-zinc mine that operated from 1999 to 2015, producing about 1 Mt/y of zinc concentrate as the third largest zinc mine in the world. At completion of mining, the tailings contained 78.9 Mt. New Century Resources headed by Pat and John acquired the mine in 2017 from MMG and tailings reprocessing commenced in 2018 after an 8-month refurbishment. The process includes 10 Mt/y hydraulic mining of tailings, followed by flotation, producing about 270,000 t/y of zinc concentrate, with reprocessing to be completed by 2027."

That story and model really shows Future Element's track record in that space. "New Century was then sold to Sibanye Stillwater in early 2023, that freed Pat and John up, along with myself and Dennis Gibson to start Future Element. Through the New Century experience, we have built up an investor base that is interested in tailings remediation projects. It's not about the technologies in isolation, we bring the capital, the technology and operational capability to develop the projects that deliver the desired environmental and financial outcomes for miners."

Passive treatment methods for AMD

Stantec has been looking at passive treatment of mine waters and ***IM*** recently caught up with Guadalupe Fattore, its Chemical and Environmental Engineer - Mine Water Treatment. She states: "Mineral extraction and processing are potential sources of surface water and groundwater contamination when acid mine drainage (AMD) is generated, which may persist after the mine is closed. For treatment of AMD, the most effective and economical water treatment systems will be desired for reclamation of the mine sites. Therefore, passive treatment technologies should be considered for applications where their efficiency has been proven and which have a low cost of operation and maintenance with respect to active treatment systems."

Passive treatment methods are based on physical, chemical, and biological processes in which the pH and Eh conditions are adjusted. The objective is to enhance the formation of insoluble precipitates and the retention of metal cations, under either oxidising or reducing conditions. The dilemma faced by passive treatment designers is selecting the appropriate technology to treat AMD since it is a sequential process that usually requires various passive technologies installed in series.

The most common passive treatment methods include aerobic wetlands and biochemical reactors (BCRs). Less conventional passive treatments involve terraces for iron removal (IT) and limestone beds for manganese removal (MRB). The primary objectives of these passive technologies are to raise pH, precipitate metals, reduce sulfate concentration, and removal of suspended solids. Designers of such treatment systems face the challenge of selecting the appropriate technology to address AMD.

Typically, passive systems use alkaline materials to neutralise acidity, organic substrates to create reducing conditions, and manure to introduce bacteria that reduce sulphate to sulphide, which reacts with metals, forming insoluble precipitates.

Fattore recently used four passive treatment technologies for a pilot plant for the treatment of AMD from an abandoned underground mine. The passive treatment system consisted of a terrace for iron removal, a biochemical reactor, an aerobic wetland, and a manganese removal bed. The pilot plant results indicated that the AMD treatment with a circumneutral pH was effective, and the metal concentrations complied with the discharge limits. The only parameter that reported concentrations above the limit was the biochemical oxygen demand.

Fattore comments: "Passive treatment systems offer an efficient and cost-effective approach for addressing AMD, particularly towards the end of the mine's operational life. When a mine generates AMD, it faces the need for ongoing treatment, that may not be cost effective for the mine. However, in cases where AMD flows are relatively low, passive treatment systems can also be utilised for water management."

She adds that iron terraces, wetlands, and manganese removal beds are also utilised for metal removal. "In this particular study, they were incorporated to enhance the efficiency of the BCR, thereby enhancing the overall performance of the passive treatment system. Interestingly, the BCR demonstrated greater efficiency compared to other passive technologies. However, due to the specific oxidising conditions required for manganese removal, an MRB was essential in this passive system."

The IT, the BCR, and the wetland effectively reduced iron concentrations to levels below the recommended threshold (0.5 mg/L) specified in the Manganese Removal Bed Module Overview, AMDTreat. However, the MRB achieved only 50% efficiency due to the wetland's incomplete removal of biochemical oxygen demand, resulting in oxygen depletion within the MRB and inadequate water oxygenation.

The effluent from this pilot-scale passive treatment system she says met the specific discharge limits for the site, except for the Biological Oxygen Demand, which was slightly above the limit. However, after approximately six months , when the BCR reached equilibrium, there was a significant decrease in BOD.

She concludes: "In the design and configuration of the treatment system, terrain topography must be taken into account to ensure gravity flow and proper circulation and distribution of influent within the system. It is essential to maximise hydraulic retention time so that contaminated water comes into contact with the materials used in these passive technologies. Other important aspects to consider include the available land area for construction, flow rate,

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and the impact of temperature changes. Furthermore, passive treatment is a holistic approach for water management, that is site specific and is sustainable."

DELKOR on dewatering

The installation of a **DELKOR** Paste Thickener to treat iron ore tailings at a plant in India has resulted in significantly reduced water usage, which, in turn, results in environmental benefits for a water-stressed country. The 15 m diameter paste thickener was ordered to increase water recovery within the process plant and increase the life of the existing tailings dam by pumping lesser amount of slurry to it.

Previously, using a conventional thickener, the mine pumped an underflow with 20-25% (w/w) solids directly to the tailings dam, leading to a high loss of water. With the installation of the paste thickener, which was ordered in 2021 and commissioned in 2022, the solids in the underflow have increased to 50-55% (w/w), increasing the process water recovery to 78-83% within the plant. This, in turn, has resulted in a significant reduction in the plant's freshwater intake. There has also been a significant reduction in the drying time required by the discharged paste in the tailings dam, which in turn has increased the life span of the tailings dam.

The scope of work covered design, engineering, fabrication and supply of the paste thickener, featuring a forced dilution feed well, with sheer thinning system. It also included design and engineering of the tailings disposal system, featuring a paste pumping system with multiple discharge points for uniform spread inside the tailings dam, plus engineering of ancillary equipment.

"DELKOR has been proudly associated with this client for nearly 20 years, having previously supplied 16 high-rate thickeners, with diameters ranging from 1 m to 65 m," says Indu Bhushan Jha, DELKOR Managing Director. "We appreciate the ongoing loyalty of such a major steel manufacturer and commend our DELKOR team for providing the quality of service and technologies that have resulted in our client continuing to support us."

Rajiv Krishnamurthy, DELKOR Executive Director, told ***IM***: "DELKOR, our **TAKRAF Group** brand focused on liquid/solid separation, is a leader in dewatering technology for the minerals processing industry. Our portfolio of dewatering solutions includes thickeners, horizontal vacuum belt filters (HBFs), and filter presses. These solutions significantly increase water recovery within a plant, which in turn significantly reduces a plant's dependence on fresh water supply. Sustainable water management, together with safety, are increasingly important topics for mining operations, investors and stakeholders around the world; especially in areas where water conservation is critical. With a focus on sustainability, our DELKOR equipment ensures highly efficient and efficient liquid/solid separation and wet processing solutions. In fact, our Group is also ideally positioned to support our clients towards the next significant step in the mining industry's move towards greater environmental sustainability - the transition from wet to dry tailings deposits. This is an area in which the combined strengths of our TAKRAF and DELKOR portfolios will provide for fully integrated solutions that make the difference."

FLSmidth and dry processing for water savings

Oman-based mining company Vulcan Pelletizing recently placed an order for a range of **FLSmidth** mineral processing technologies to be installed at their upcoming pelletisation plant. The technologies will both reduce water usage and drive operational efficiency. With water being a scarce resource in the Middle East, dry grinding is well-suited to minimise its consumption as well as drive operational efficiency when downstream processing does not require water.

FLSmidth has a long-standing history in supplying dry grinding solutions and has a market-leading position with over 80 sites operating more than 150 FLSmidth dry grinding mills and air separators on various ores, including gold, nickel, lead, zinc, phosphate and iron ore. Its dry grinding portfolio was further strengthened through the Mining Technologies acquisition.

Reducing water is a key focus area for this customer and one of the key reasons FLSmidth says for having chosen its well-proven, dry grinding technologies. This order includes the delivery of two dry grinding mills, a wet grinding ball mill as well as high efficiency air separators, hydrocyclones and pumps. The equipment is due to be delivered during 2025. "Sustainable mining is not only a matter of reducing CO_2 emissions. Reducing water usage in mineral processing stands at the forefront of technologies requested by miners, particularly in water stressed regions and where downstream processing also is dry. This order confirms both our broad, market-leading position within dry grinding as well as supports our MissionZero ambition," comments Mikko Keto, CEO at FLSmidth.

FLS options for dry grinding include Vertical Roller Mills

Sykes launches XH250 dewatering pump aimed at mining

Sykes Group, a leading name in the realm of dewatering pump solutions, has recently launched its latest innovation, the Sykes/Primax XH250 for mining and quarry applications. The XH250 it says "is set to revolutionise dewatering operations in these sectors, offering a reliable solution for operations that are continually expanding, reaching greater depths and widths."

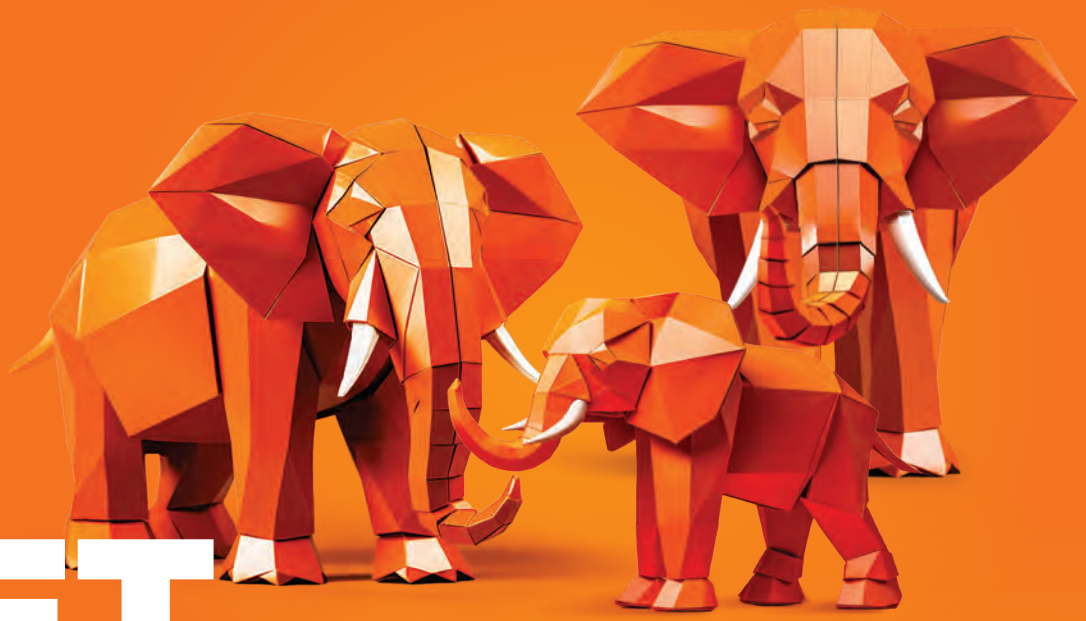
The pump, which complements Sykes' existing range of Extra High Head pumps, delivers higher heads and flow rates than its predecessors to ensure consistent equipment access to all areas of mining and quarry sites, the company says.

Key features of the Sykes XH250 as stated by the company include:

- Versatile drive options: The XH250 is available in both diesel- and electric-drive configurations, and it can be mounted on skids, trailers, or pontoons;
- Impressive performance: The XH250 is engineered to deliver 200 litres/second at 220 m or 250 litres/second at 200 m, ensuring reliable and efficient dewatering;
- Innovative pump design: The pump's design incorporates several key features to enhance its longevity and performance, including extraordinary shaft stiffness ratios, multiple priming options, advanced bearing arrangements and exceptional sealing solutions;
- Front and rear wear plates: Sykes Pumps' inclusion of wear plates offers the ability to make fine adjustments to the impeller-wear plate clearance, enabling customers to restore pump efficiency without the need for extensive overhauls;
- Material options: the Sykes XH250 is available with various material options to suit specific applications, including 316 SS Impeller, wear plates, and SG iron Volute, among others. Other options are Full 316 SS, CS340, CS500, CD4MCU, H7A SS, CD4MCU, SAF2205 and SAF2507.

The company concluded: "The Sykes XH250 is a testament to our commitment to providing efficient and reliable dewatering solutions for the mining and quarry industries." Sykes Group recently became part of the Atlas Copco Group Power and Flow Division. In addition to the XH250, Sykes told ***IM*** that it has many cases of

SYKES



GET PUMPED.

Introducing the all new XH250

Crafted to excel across diverse sectors, the XH250 embodies our dedication to cutting-edge dewatering solutions. In a landscape where productivity is paramount, this powerhouse sets new standards for effectiveness. Engineered to conquer the toughest challenges, the XH250 empowers operations with unparalleled flow and head. Embrace the future of dewatering with the XH250, where innovation meets results. So, if you're facing water issues, solve them with a Sykes.

For more information on how Sykes can solve your water problems please reach out to your local representative, email us at info@sykesgroup.com.

Find out more at sykesgroup.com

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Managing water data effectively

EnviroSys is an environmental compliance management and monitoring software solution from **acQuire** used by mining, government, water and energy companies worldwide. In mining, for example, it allows operations to efficiently capture, validate, monitor, analyse and report any type of water-related data. ***IM*** got some more insight into the solution from Stuart van de Water, acQuire's Environmental Leader.

Q Why is it important for miners to have a single source of truth for their water management and monitoring data?

A Managing water and other environmental monitoring data is a multi-disciplinary endeavour. Miners are expected to capture a broad variety of data, in different formats across labs, devices, or other sensors, and at differing frequencies. If data is not stored and managed in a single place, and in a consistent manner, it becomes challenging to respond to regulatory and reporting requirements in a timely, accurate and verifiable way. This puts your operations at risk of non-compliance simply through poor data management and governance.

Q Has consolidation of this data been partly driven by more stringent environmental compliance hurdles relating to water use and management?

A Yes absolutely, it's a big factor. It's not enough to simply claim good environmental compliance, you need to be able to prove it, to "show your workings." Not having this data consolidated, or a lack of best-practice data management processes does not instil confidence in stakeholders who are shining a light on the compliance of your water use and management practices. The introduction of more stringent ESG compliance hurdles, such as emissions management, has shifted the needle. Having auditable and timely environmental data has moved from being a luxury to a necessity.

Q How does EnviroSys actually capture data and how does it help mines validate their water compliance?

A EnviroSys, acQuire's environmental data management solution, supports its customers by ensuring they can load environmental data from anywhere, in any type, at any frequency they require. This is with as much automation as possible, to remove the manual handling element. acQuire ensures its EnviroSys customers have tools to correct ingestion issues in the system itself, rather than outside of it where audit trails and data chain of custody are impossible. Users can also track and verify their datasets, removing any nasty surprises of missing data come reporting time. Our philosophy is "no data left behind". EnviroSys gives mines the ability to analyse, validate, verify and report across their environmental datasets and to answer "are we compliant right now?" instantly and with confidence.

Q Can you comment on the Nova Network program you have set up and the potential that has for water management in mining? Which consulting firms are you working with?

A The Nova Network Program is a collaboration between acQuire and consulting companies to provide high-quality data management services to natural resources companies around the world. The program allows us to focus on our EnviroSys solution and its technical support, whilst our partners can service the data management, training and expansion needs of our customers, once EnviroSys is in place. Often, our partners come from a consulting or operations background, so when it comes to the customers they service, they can offer best-practice and a wealth of knowledge, especially in the water management space.

Q What would you say makes EnviroSys stand out from other software offerings in the market related to consolidating water management data?

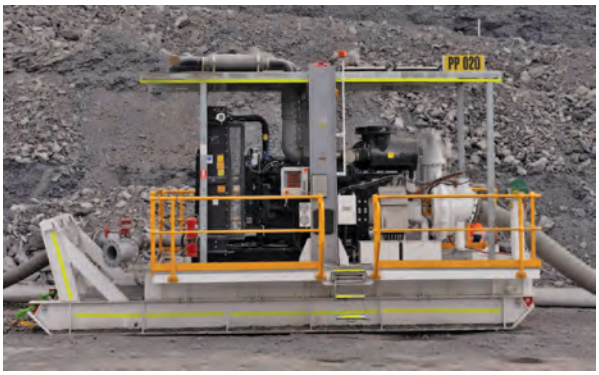
A We focus on doing the core environmental and water data management really well. Our focus is on delivering a system that will be used by humans – how they work, the tasks they need to perform and the reporting requirements they need to respond to, such as emissions reporting and other ESG considerations. EnviroSys offers a simple, unified and consistent experience for our users. We also put great emphasis on what we call our "support ecosystem" – during and post-implementation, our users are supported by our online help, knowledge base, self-paced online learning and our support service desk.

Q Is the water data world becoming more complex with mines using more sensors and surveying methods - and is this underlying the need for an all-encompassing software solution even more?

A The fundamentals of data management are the same, it's just shifting where data is coming from. The question now is how to handle different protocols, sensors, formats and frequency of data. Increasing the number of sensors means companies need to understand how this will change the frequency of data coming in, and their capacity to manage it. If you do the sums on sensor data being reported at 1-minute, 10-minute or hourly intervals – this can mean an exponential jump in the size of your datasets, where you still need to be able to assess compliance in real-time. Your solution needs to be scalable and based on best-practice technical architectures and technology. But, of course, the solution can't only be about big data and high-capacity processing. Companies also need to know how to handle the much less frequent sampling data – you need to place a high importance on both at the same time, which EnviroSys excels in.

other pumps in this range XH 100, XH150, XH200 and XH300 having installed in mining worldwide.

Customers for the XH250 include coal miner Bengalla New Hope Group in Australia. Scott Cannon, Pumping Supervisor, Bengalla Mining Company: "One of the challenges Bengalla had was as the mine gets deeper and the mining process didn't allow us to pump out one end of the strip, it made us have to pump the water a lot higher than what we'd previously had to do. We were running it through a few staging pumps, and that's why we looked at the XH250 as an option so we can remove one of the staging pumps because of the ability for it to pump a lot more head. Sykes was able to tailor-make walk platforms around the XH250 for Bengalla to assist in the maintenance and the pump crews getting on and off the platforms." Rodney Hamson, also from Bengalla, adds: "We only get a short period of time we can pump water, because with the draglines behind us and the



Sykes Group recently launched the Sykes/Primax XH250

way it moves, we've got to get in and remove the water as quick as we can so they can recover the coal."

BQE Water and a disruptive approach to selenium removal

BQE Water made a major announcement in February 2024 when it advised that it had completed the commissioning phase and transitioned to the operating phase of the agreement for a water treatment plant at a base metal mine in the southwestern US. Utilising its award winning Selen-IX™ process technology, BQE Water treats mine impacted waters, removing selenium to below 2 ppb (parts per billion), as well as dissolved metals, in compliance with applicable effluent quality regulations.

Under the agreement, BQE Water is responsible for clean water production for environmental discharge. Compensation for operations services consists of a base monthly fee and a supplemental fee for additional water treated over and above the base. The base monthly fee is payable regardless of the volume of water reporting to treatment but is subject to the plant being available for treatment. Both fees are paid subject to the plant effluent meeting the target effluent water quality.

Since the completion of commissioning, BQE Water says the plant has been operating 24/7 with an overall plant availability more than 95%. It is expected to run year-round and treat up to 4,500 gallons of water per minute, making it the largest Selen-IX plant currently in operation. The plant first removes a host of dissolved metals, followed by selenium removal. The key aspects of the plant design that led to the selection of Selen-IX technology for selenium removal included the stringent selenium effluent limit, the requirement for a rapid ramp-up in selenium removal capacity depending on flow and selenium concentrations, and the need to produce a stable non-hazardous residue.

David Kratochvil, President & CEO at BQE Water told ***IM***: "This project is a major development for us but it is important to emphasise that addressing selenium in waters is not all we do – today it probably represents about a quarter of our active projects. It includes a broad range of water treatment for environmental compliance including: achievement of ultralow discharge limits for a host of metals and cyanide; the recycling of cyanide using SART, and ion exchange based technologies to selectively remove sulphate, ammonia, and thiosalts which are regulated directly or through effluent toxicity. The common denominator for all our projects is reduction of waste and generation of residues that are suitable for re-use."

But undoubtedly, selenium is a big problem in mining – and BQE Water's journey in that respect began way back in 2012 with a reaction to two things. Kratochvil: "One – we started to get a lot of specific enquiries from mining companies around the world about dealing with selenium so there was a tangible market interest uptick. And at the same time, a major consultancy released a report stating that the best available technology to treat selenium in mining was biological treatment. But this was based on two installations of selenium removal technology at FGD plants in coal fired power plants, an application that could not be more different from mine waters with an entirely different setting and criteria including the flow, stability of the flow, the temperature of the water, what's in the water, the discharge limit and receiving environment – everything is different. The reality is while consultancies have a role to play, fundamentally they tend not to be the technology innovators themselves with the associated in-house R&D – they usually apply what has been done before and tend to be conservative in terms of not wanting to take a risk with a new solution, even if it has a clear potential to address the problem in a more effective way."

BQE Water started from the basis that every mine and every deposit is different therefore the water quality is different. "We thought, why not be contrarian and look at something non-biological, as we believed the mining industry needs a technology that to be able to adapt to changes in flow and water quality, that will still work when the water is very cold or stops flowing for a few months, and in general not as difficult to maintain as a biological set-up. We got funding from a couple of mining companies who at that time were going through stages of permitting and in their projects, selenium had been flagged as one of the major environmental issues. So they had a lot at stake and they did not like the biological approach so that's why they helped us fund the tech development."

But why is selenium a problem in mining and how did it become a problem? Kratochvil says it has always been there but has not been measured and the detection limits were not where they are today. But more importantly, the aquatic toxicology of selenium is a relatively new science and one that is still fast evolving. "The understanding of its impacts on the receiving environment is increasing – particularly that the nature of selenium toxicity is not acute rather it is chronic long term through genetic mutations in organisms and you need to have seen generations of organisms before you actually see an effect. So if you start a mine, and you have selenium in your discharge, you are unlikely to see effects for maybe ten years. But eventually you will see them and by then it is too late. The danger for the industry and something the regulators recognised, was that by the time you start seeing effects the bioaccumulation has already started and it is very difficult to turn the dial back – so the industry needed something proactive and that would catch it early using conservative regulation limits."

In very low levels, selenium is a micro nutrient – the problem is that aquatic organisms are way more sensitive to it than humans. Drinking water standards are orders of magnitude greater than those for fish. It starts in micro algae and plankton then invertebrates and fish and so on. Another important piece is that the first step – the way selenium update happens between the water and the algae – depends on a lot of site specific factors such as water flow rate – in lakes and marshes bioaccumulation starts much more quickly than in a river. "While the biological systems can remove 90% or so of the inorganic selenium, a small portion of what is left is converted from the inorganic form which is not as bio-accumulative, as the organo forms that the biological approaches actually generate in small amounts. Those small amounts are orders or magnitude more bio-accumulative than the inorganic selenium that was in the water in the first place. So in some ways the biological treatment can, in some cases, make the effluent more toxic. This was not appreciated until people started building these plants and measuring different forms of selenium in effluent and the regulators said you not only have to sample the water but also take samples of fish tissue – where levels were actually going up faster than before the treatment plant was put in."

What happens to selenium at the end of treatment? Kratochvil: "It goes into a residue and just by its nature, the biological residue is really unstable. If you put in into a conventional landfill, it will get into the leachate; you can hope for the best and store it under anaerobic conditions. But with an inorganic approach like

ours – you are not generating any of the organic selenium species, it just filters the selenium out in the first place plus you can treat on demand, and the water temperature does not matter. Plus you generate a solid inorganic residue that even has potential markets like steelmaking. And none of the biological approaches alone can reach the regulated limits in the receiving environment without relying on dilution downstream."

How does Selen-IX actually work? This process concentrates the selenium into a small volume of brine solution that is treated with electrochemical cells to precipitate the selenium as a stable iron-selenium solid. After the solids are separated from the liquid, the brine solution is recycled back to the ion exchange circuit, eliminating waste liquid brine. XRD and TCLP analysis have verified the solids to be non-toxic. Selen-IX units are compact modules with a small footprint and can be easily deployed in remote locations to treat multiple discharge points just as they can for one single big discharge point.

Selen-IX has US and Canadian patents in place as that is currently where the regulations are the toughest on selenium. BQE Water already sees potential elsewhere, however, for example there is a new project in Peru that has already flagged selenium. Plus there is no doubt that it is going to be present in many of the mined deposits worldwide. It also cuts across different commodities – copper, gold, coal, zinc and so on. It is just isn't on the regulatory frameworks of other major mining countries – yet. It is also worth pointing out that many of the mines in the US and Canada are discharging water into relatively pristine natural habitats that are ecologically sensitive. That is also the case in many other regions but not necessarily at every site.

BQE Water has moved through concept, proving at lab and pilot scale plus numerous demos and is now building full scale treatment plants as outlined in the recent project announcement. This client cannot be revealed due to NDAs but is one of the major global base metal producers. However, other clients like Seabridge Gold, which used Selen-IX to secure regulatory approvals for the KSM project, have been public about their use of the technology and their support of it. "They knew they had time before implementing selenium treatment, so they were able to look at emerging technologies and take advantages of innovation, and seek out the best possible solution for their project rather than just going with the biological approach that was the only commercially available technology at the time they began their search. Also the world is changing – many miners are not waiting until regulators tell them to do things – they want to be proactive where they can as they want to be sustainable and be upfront with local communities in what they are doing."

Veolia Water Technologies and new developments in selenium removal

Further to the above discussion on biological versus inorganic approaches to selenium removal the biological methods themselves are also evolving, and ***IM*** also spoke to **Veolia Water Technologies**. It stated: "Selenium is a metalloid known to be toxic to living organisms in high concentration, but is widely present in the environment at low concentrations. Its most common form in water, selenates, is similar to sulphates and, to a lesser extent, to nitrates. Due to this resemblance and due to its solubility, treatment of selenates is complicated, which can cause many headaches to efficiently target its removal."

Veolia summarised what it sees as the main avenues currently observed for selenium removal as follows: reverse osmosis separates molecules based on their size. Selenates, being relatively large molecules, are easy to separate. However, in mine effluents, many large molecules can be found, including molecules leading to membrane fouling and scaling. This can result in high concentrate generation, which needs to be disposed of. This approach can be good for applications where disposal of a large waste stream is available.

- Ion exchange separates molecules based on their charge. Ion exchange resins have been developed to bind selenates effectively. However, these are subject to competition from similar molecules such as nitrates and sulphates. High molecule binding potential

increases the requirements for resins regeneration, resulting in an increase of the volume of waste to reject. This approach is therefore good on low nitrates and sulphates concentrations mine effluents.

- Chemical reduction with zero-valent iron (ZVI) aims at the chemical reduction of selenates to selenites using ZVI iron. The selenite is then co-precipitated on iron hydroxide flocs. However, ZVI iron will also reduce nitrates to nitrites, leading to both increase in the ZVI consumption and nitrites production, a by-product toxic to many fish species. ZVI oxidizes to ferrous iron, producing an effluent containing high soluble iron concentration, which is toxic as well and needs to be removed before discharge.
- Biological treatment systems are based on microbial reduction of selenates and selenites to elemental selenium. Elemental selenium is insoluble in water and can be removed using a solids separation system to produce a selenium-free water.

Veolia adds: "Biological reduction is by far the most common selenium treatment process and several biological processes for selenium reduction are available. There are, however, a few considerations that should be considered with biological selenium reduction. Nitrates compete with selenites and selenates; it should be removed prior to selenium reduction to optimise the biological reaction. Elemental selenium particles are difficult to separate due to their size and lack of charge. It is also easily oxidisable, which make sludge disposal complicated as to prevent selenium release over time; reaction kinetics are slow, which translates into large reactors and hence high costs."

It continues: "In addition, due to the low selenium concentration targeted at the effluent, the reductive conditions in the biological system are as such that the transformation of selenates to elemental selenium can lead to the formation of selenide, notably due to longest retention time and in the attempt to transform very low concentrations to elemental selenium. Selenide is a known precursor to organo-selenium species."

Veolia like BQE Water points out that the issue of selenium toxicity is complex. "In recent years a number of large-scale bird mortality incidents have been associated with selenium. Examples include birds feeding and nesting at the Kesterson Reservoir in the San Joaquin Valley, CA (1983-1985), eared grebes at the Salton Sea, CA (1992) and, again, eared grebes at the Great Salt Lake, UT (2011). While selenium has been

Xylem & Evoqua create leading pure play water company

In May 2023, Xylem Inc completed its acquisition of Evoqua Water Technologies Corp, a leader in mission-critical water treatment solutions and services. The combination created the world's most advanced platform of capabilities to address customers' and communities' critical water challenges. Key markets include mining, and ***IM*** caught up with Ken Albaugh, Director of Sales and Services at Xylem, about the strengths and significance of the combination

Q What does the combination of Xylem and Evoqua bring to mining in terms of a combined and comprehensive offering?

A Mine operations rarely fit a mould, each having unique challenges. One constant, however, is that effective water management is critical to operational success and environmental stewardship. This requires diverse, flexible solutions. The combination of Xylem and Evoqua meets this need, bringing a comprehensive suite of solutions to enable the mining sector to manage the full cycle of water challenges. Our team has a wealth of mining expertise and experience in moving and treating water which enables us to create bespoke solutions for every customer challenge. While solutions vary in purpose and scope depending on the requirements of a mine, one common goal is compliance. From managing mine water runoff to feed water, we can provide holistic solutions to ensure that discharge back into the environment will meet or exceed requirements, maximising operational uptime and reducing the risk of fines. Our comprehensive offering reduces the complexity of managing multiple vendors and technologies and leads to a more streamlined, solutions-focused delivery through a single point of contact. We can even offer mobile solutions for water movement and treatment for temporary projects during construction or repairs.

Q Are there any specific examples of where Evoqua water treatment technology could potentially be combined with Xylem dewatering solutions for example as a complementary offering?

A Our customers now have access to a complete offering that can help them meet environmental compliance and operational efficiency goals, in tandem. For example, in a quarry project on the west coast of the US, we combine market-leading dewatering technology to pump water with a best-in-class treatment system. Water is treated before it is discharged back into the environment to ensure compliance with permit requirements. Also in the western US, we are onsite at an in-situ mine supporting its copper ore processing operation. Our system treats the low pH wastewater and ensures the water quality is returned to its natural state, using a combination of dewatering capabilities and treatment solutions. These integrated solutions are commonly requested by our customers to manage the physical movement of water at mining sites and treat it to ensure water quality and compliance. Some customers require more complex or customised dewatering/treatment combinations and through our combined platform, we can meet those needs.

Q With the even greater mining industry focus on tackling tailings challenges, is this an area where both Xylem and Evoqua can bring different approaches to bear?

A Regarding tailings management, our focus is primarily on ensuring environmental compliance through water treatment solutions, which might involve treating runoff water or managing the discharge of excess water into natural water bodies to ensure it meets regulatory requirements. For instance, when a tailings dam is closed, Xylem can now bring an end-to-end solution to move, treat, and discharge water to meet environmental compliance standards. While we are not directly involved in tailings processing, Xylem provides equipment that can be part of a broader tailings management solution, including the use of filter presses and the pressing of tailings into a cake form, which is a method of dry stacking. This approach reduces the environmental impact of tailings storage by minimising the need for large tailings dams and the associated risks.

The combination of Xylem and Evoqua has created a unique integrated offering of water solutions for mining

associated with the die-offs, the mechanism involved is not yet well understood. It is, however, likely that these die-offs are complex events caused by bioaccumulation of selenium through the food chain up to a point where the selenium concentration became high enough that it caused acute toxicity in the predators. It is generally understood that the selenium tendency to bioaccumulate depends on its form, with organo-selenium much more likely to bioaccumulate than any other selenium sources."

While decreasing total selenium concentration is important, it is also important to try to lower the potential for bioaccumulation of the residual selenium after treatment. To address this issue, Veolia Water Technologies has developed Tracer™ Se, an "innovative selenium removal process which not only aims at lowering total selenium concentration but to limit and address part of the production of organo-selenium species prior to discharge."

The Tracer Se process combines biological reduction of selenates to selenites, removal of selenites and biomass under reducing conditions, and biological reoxygenation of the water. The Tracer Se process was initially designed to limit the biological reduction, aiming the production of selenite instead of elemental selenium. It has the advantage of considerable footprint reduction, due to higher kinetics.

The mine effluent is first directed to a biological reduction reactor containing biomass and operated under denitrifying (anaerobic) conditions, typically using a Moving Bed Biofilm Reactor (MBBR). In this biological reduction reactor, selenates are biologically reduced by the biomass to selenites or absorbed on said biomass. The oxidation-reduction potential (ORP) in the biological reduction is controlled to minimize further reduction of selenite species to elemental selenium and selenide.

The water containing the selenium and sloughed biomass is then directed to a precipitation reactor. While maintaining reducing conditions, a coagulant such as a ferric or aluminium salt is mixed with the water. By controlling the pH and using sludge recirculation to age the sludge, solids having adsorption sites are formed. Some selenium species such as selenites are adsorbed onto these sites. The solids with adsorbed selenium, in addition to the biomass containing adsorbed selenium, are separated from the water, typically using a ballasted flocculation settler such as Veolia's Actiflo® High-Rate Clarifier.

The water is further treated in a second biological reactor under aerobic conditions where the water is subjected to reoxygenation. In this stage, reduced selenium species present in the water are oxidized, thus limiting the potential of releasing organo-selenium to the environment, in addition to providing dissolved oxygen back to the water so it will not be toxic to aquatic life.

Veolia states: "Extensive laboratory testing, which has been conducted on a typical metallurgic coal mine effluent, has shown that Tracer Se mostly captured the selenate from the influent water within the biological treatment biomass, operating at high kinetic. The adsorbed selenium, as well as some selenite from the biological reduction, were efficiently captured in the metal precipitation and ballasted flocculation step. Finally, the reoxidation biological reactor was shown to be highly efficient in oxidising reduced selenium species such as harmful organo-selenium, and the overall treatment chain can achieve a global selenium removal down to 5 µg/L with low organo-selenium concentrations."

It concludes: "Selenium removal is a challenge as there is no ultimate water treatment applicable for every situation. The importance of selenium removal is increasing, as its toxicity is getting more documented but with little certainty as for how selenium is so toxic. Veolia's Tracer Se aims to prevent selenium toxicity by acting both on providing a low selenium concentration at the effluent as well as lowering as much as possible the organo-selenium concentration, which is one of the main hypotheses to explain most of the die-off events observed in the past few years." IM

In 2023, Liebherr Mining achieved its first repower of a diesel-drive machine to electric drive, converting a R 9400 in Australia for Fortescue

Digging by design

Conversions to electric are becoming more common for hydraulic excavators, while remote control operation also remains a focus. GET solutions are also getting more advanced, reports Paul Moore

The mining excavator market is evolving – with more focus on electrification, and as part of that a lot of mines are looking at conversion, sometimes called repowers, as an option to reduce emissions from existing machines. Fortescue earlier this year delivered a prototype Offboard Power Unit to power a converted Liebherr electric R 9400 E excavator previously delivered to the Christmas Creek iron ore operation, part of the Chichester Hub. Trials of the machine using hydrogen fuel cell derived power have already begun.

The **Liebherr** R 9400 was originally supplied in 2010 as a diesel machine and was nearing the end of its operating life when Liebherr and Fortescue successfully retrofitted it to electric (cable powered) operation as the R 9400 E. This was Liebherr Mining's first repower of a diesel-drive machine to electric drive and is also the first Liebherr electric excavator to operate in Australia.

The Offboard Power Unit is described in globally patent pending documents filed by Fortescue as follows: "A power supply system is provided for supplying electrical power for operation of heavy equipment such as mining machinery, the power supply system having: a hydrogen fuel cell module for generating electrical power from stored hydrogen; a power electronics circuit coupled to receive electrical power generated by the fuel cell module, and having at least one output for supplying electrical power generated by the fuel cell module to an external equipment load; a battery module coupled to the power electronics circuit to allow charging of cells in the battery module using electrical power generated by the fuel cell module, and discharging of the battery cells through the at least one power electronics circuit output on demand."

The document adds: "Mining, particularly open-pit mining, uses large machines for efficiency of scale. In order to power such machines using non-polluting electricity can be challenging in view of the location, environment and mode of use of the machines. Embodiments of the present invention provide an offboard power unit (OPU) for supplying electrical power to operate heavy equipment such as a moveable mining machine. The power unit is designed to be mobile with the equipment being powered. Energy for the OPU is generated from stored hydrogen through use of hydrogen fuel cells (HFCs). By sourcing 'green' hydrogen (eg hydrogen generated by electrolysis of water using sustainable electricity), use of the OPU according to embodiments of the invention to power mining operations can be close to 'carbon neutral' insofar as neither the energy supplied nor its use in the mining site produces carbon pollution emissions."

It adds: "The trailing cable in use carries a substantial level of electrical current and/or high voltage between the OPU and the equipment, and should therefore be sufficiently robust and insulated as for use in a mining pit or similar. The trailing cable may have a length in the order of 300 metres, which allows the equipment a range of movement without needing to relocate the OPU. Since the equipment is typically mobile and trails the cable behind it, there is preferably some kind of strong anchoring connection between the cable end and the equipment to prevent unintended disconnection physically or electrically. One way of anchoring is to wind an end portion of the cable around a circular structure that uses friction to maintain lock. The structure is connected to the equipment, but is able to pivot to allow a greater degree of freedom for movement. In addition or alternatively a cable reel of commercial variety may be included, either at the equipment end or the OPU end, for use in managing the length of cable deployed at a given time according to position and/or movement of the vehicle relative to the OPU. In consideration of magnetic flux that may be generated by current flowing through cable wound on the reel, it may be desirable to limit how many layers of cable can be wound on the reel. This is then determined by how large the reel is to accommodate more cable before needing to layer the cable on the drum."

The document then adds: "Different forms of electrically driven mining machinery may require significantly different electrical supply characteristics. For example, in terms of power requirements, the aforementioned DTH Drill (eg Atlas Copco D65) may require electrical supply power in the order of 400 kW, a large platform drill rig (eg Epiroc PV271 Blast Hole Drill with electric motor option) may need around 700 kW supply, whereas even a small (250 t) mining excavator (eg Liebherr R 9250 E with electric motor option) may require 1,000 kW or more in electrical supply power to operate. Moreover, some equipment needs direct current supply whilst others use alternating current. Supply voltage requirements can vary also, along with duty cycles."

On scalability the description also states: "The range of power requirements is addressed by embodiments of the invention by allowing each of the fuel cell, battery and electronics modules to be scalable and independently configurable in capacity. This flexibility in design of the offboard power unit provides opportunity to tailor sizing of battery and hydrogen fuel cells, in particular, to suit equipment applications. Hydrogen storage can also be tailored to suit equipment duty cycle and operational requirements."

The R 9400 repower process

Back to Liebherr and the excavator conversion itself. "Approximately 60% of an electric-powered Liebherr mining excavator is the same as a diesel-driven machine, which helps to simplify the repowering process" explained Chris Di-

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Nardo, Project Manager, New Machine Deliveries, Liebherr-Australia Pty Ltd in a recent article posted by the company. “Once this R 9400 had been removed from its operations in Western Australia, the base machine was returned to our branch in Perth, where the conversion could begin.”

Among the changes necessary for the R 9400 to become an R 9400 E, the diesel powerpack and fuel tank needed to be removed and replaced with their electric counterparts – in this case, an electric-drive powerpack and a high voltage electric cabinet respectively. Components needed in the diesel-drive R 9400 – like the water-cooling radiators, fans, exhaust, and air intake systems – were made redundant with the introduction of the electric-drive powerpack. However, the rotary connection was a unique case: in order to accommodate the high voltage interface between the upper- and undercarriage of the R 9400 E, an entirely new rotary connection needed to be installed.

In order to simplify major machine maintenance for customers, Liebherr recommends that repowers occur when a machine is due for a major service or component exchange. So while the R 9400 was being transitioned from diesel to electric power, major components that had achieved service life were also exchanged. Performing major maintenance in this way also has the benefit of making the process more cost-effective for customers. Once the new electric-drive modules were installed, connections completed, and systems checked, the repowered R 9400 E was then ‘powered up’ to energise the excavator’s operational systems. The R 9400 E requires 6,600 volts at 50 hertz for its power up process and then the electric motor and hydraulics can be ‘started and run up.’

To minimise the inrush current needed to start the electric motor, Liebherr developed a specialised system that consists of high voltage transformers. This system of transformers reduces the current required from the customer’s power grid to avoid excessive network disturbance.

Although the repower process is not overly complicated, specific expertise from Liebherr’s excavator factory in Colmar, France, was required to support the Liebherr team in Australia with its first diesel to electric repower project. “Repowering the R 9400 was an exciting challenge for our team, but one that they quickly overcame,” says Di-Nardo. “Most of the people working on this project had only worked with diesel powered machines previously. However, thanks to the combined efforts of more experienced team members here in Australia and the engineering assistance from our excavator factory, the team was able to complete the project tasks safely and on time.”

Weir ESCO and next gen GET

ESCO, a division of **Weir Group**, engineers and manufactures mission-critical wear & replacement products for mining, construction & industrial applications. ***IM*** caught up with the world leader in ground engaging tools for some insight into its pioneering innovations, including a preview of its new Nexsys™ Mining System for rope shovels.

Q Are most or all your GET solutions customised packages for individual mines - is this one of the things that makes ESCO stand out in the market?

A As the world’s leading independent provider of mining GET, Weir ESCO offers a wide selection of options with maximum flexibility to best suit each mining application. Selecting the proper lip system and GET combination can influence the site’s productivity, ability to achieve key performance indicators (KPI) and operating efficiency. Weir ESCO works closely with mine personnel to provide product training and the best maintenance practices to maximise GET performance. ESCO’s field-proven Nemisys® lip system for mining class wheel loaders is a perfect example. Depending on site preferences and machine use, there are both weld-on and mechanically attached options. The weld-on system provides better penetration and lower product weight, allowing for a higher bucket payload. The mechanically attached system has a slightly higher profile but allows for easier component replacement in the pit without any hot work, reducing overall machine downtime. A broad selection of teeth, wear caps and shrouds are available to suit the site’s needs. Weir ESCO’s GET experts partner with the mine to select the best option for the machine class and application.

Q How do you actively benchmark the TCO of ESCO GET solutions versus competitors in the market?

A When considering total cost of ownership (TCO), multiple factors come into play: component cost, time required for installation and replacement, productivity, wear life and unplanned downtime are the most common. All hold a different level of importance to each mine site. As a leading supplier of GET, Weir ESCO delivers values outside of just product pricing. We collaborate with the site to evaluate their current system, whether it is a competitor’s system or a previous Weir ESCO system. Through selection of the optimal GET combination, the customer will benefit with increased efficiency and achieving critical KPIs.

As an example of the options available to customers, for an EX5600 hydraulic excavator operating in extreme applications, the Nemisys® N5 nose size would be an excellent choice. It offers a range of options to deliver optimal performance. The XHD intermediate adapters and shrouds combined with a heavy-duty point will deliver the best system reliability, wear life and minimise lip maintenance. This GET option also features extended bottom wear shoes to provide additional protection for the structural components on the underside of the cast lip to further reduce maintenance and extend lip life. For the same machine in less demanding conditions, the Nemisys® N5 V2 lip is available. It allows for smaller, lighter Nemisys N3 points and shrouds which can be used without sacrificing nose strength on the cast lip. This option saves more than 1,590 kg (3,500 lbs) over the XHD configuration, potentially increasing the bucket payload or freeing up weight that could be reallocated to additional wear protection in high wear areas of the bucket.

Q Are customers relying more on high quality GET to maximise cost per tonne in today's mining world?

A Mine digging performance expectations continue to become increasingly challenging. Customers want to maximise equipment use by extending GET system service life to better match planned maintenance schedules. One way Weir ESCO is able to provide optimal performance is through reliable GET retention and with proprietary alloys that provide an unsurpassed metallurgical advantage over OEM and competitor systems. Although all suppliers provide alloy steels, our alloys provide the best balance of superior material toughness and through-hardness. With this, Weir ESCO components deliver the best in-field performance for wear life and reduced chance of cracking or catastrophic failure. The result is improved productivity, increased GET service life and less downtime, all of which lower a mine’s cost-per-ton. In addition, all Nemisys GET components come equipped with sealed locks to minimise the effects of impacted fines for easier and faster GET replacement.

Q Is the GET market very distinct from the attachments market, ie buckets, or is it common for both to be sold in combination and does this bring the best overall results?

A Attachments serve as a primary structural component that are expected to have a long

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service life. Weir ESCO attachments are highly engineered to meet customer requirements, some of which often include optimising pass-matching between haul trucks and the attachment, overall system weight or increasing a bucket payload. Custom wear packages may be added to extend the attachment service life. Additional protective components add to a bucket's weight and may affect payload capacity. The GET system also provides protection, but additionally helps the bucket penetrate the material and efficiently fill the bucket. As an independent, global supplier of both mining GET components and attachments, Weir ESCO can optimise overall machine performance with the best match in the overall design. Pairing a Weir ESCO attachment with a premium Nemisys® lip system, operating on over 1,200 machines worldwide, allows the site to benefit from the optimal balance of penetration, loading efficiency, wear-life and reliability. If a new attachment is not needed, the Nemisys lip system can easily be installed on an existing ESCO, OEM or competitor bucket. As an alternative, Weir ESCO can quickly convert existing competitor lips to the Nemisys system using bridge adapters. This allows the site the to see the value the Nemisys system can provide over a competitor's system. Once proven, the customer can continue to use these bridge adapters until the current lip is worn out and can be replaced with a genuine full Nemisys lip system.

ESCO® has developed a new Nexsys™ GET system for rope shovels

Q In what ways has your GET business become more digital in recent years and what synergies are there with Motion Metrics in this area? Have customers become more open to widespread use of digital solutions than they were previously as there is more confidence in sensor or camera-based systems generally?

A With the integration of Motion Metrics™, Weir ESCO is now able to provide customers tools to better manage their equipment. From GET detection to fragmentation analysis, Motion Metrics™ offers a complete suite of products to help customers achieve a new level of productivity and efficiency. Coupled with Weir ESCO attachments and GET lip systems, Motion Metrics™ technologies is a group of advanced systems developed to provide a new generation of safer, sustainable and more intelligent mining. This technology is utilised in a range of systems to help mining companies operate more efficiently by streamlining processes, improving productivity and identifying potential system bottlenecks before they occur.

Q Is the GET market divided into a premium market and a commodity market - has the share of commodity products declined as customers have realised the value of premium solutions?

A There is some division of the market between premium and commodity. Although much more prevalent in the construction market, some competitors are participating in the mining markets with commodity type products. This can pose a risk with major mining machines feeding directly into crushers and not being able to rely on the GET component retention which can lead to major crusher damage, unplanned downtime and the expense from lost production. Weir ESCO provides GET systems with unsurpassed reliability that deliver the best TCO, especially over commodity based systems.

Q What are the most standout launches from ESCO over the past year, and can you give a flavor of what is to come?

A In the last year, Weir ESCO further optimised the industry leading Nemisys GET system bringing sealed locks into all tooth offerings for easier removal in even the toughest applications with severe impacted fines. In addition, through Motion Metrics, Weir ESCO launched the new ShovelMetrics™ Gen 3 system. With the Gen 3 stereoscopic 3D camera equipped with powerful LED lighting, mines can now get the images and data needed in low-light or poor visibility conditions. With over 100 years of expertise in engineering, metallurgy, fabrication and casting technology, Weir ESCO continues to innovate and raise the bar on performance capabilities. We have a new, more advanced system – the Nexsys™ Mining System for rope shovels - coming to market in the near future. The Nexsys system was developed to increase upfront value as well as provide major improvements in overall performance, reduce maintenance and extend service life. With the new Nexsys system, Weir ESCO continues to lead the industry and is once again setting the standard. The Nexsys Mining System value proposition includes a slimmer profile for better penetration and loading, plus up to 10% less system weight over the Whisler Plus™ system. A simplified rebuild requirement reduces downtime for more production plus it has improved adapter protection for longer system life for less maintenance. Exceptional system durability reduces the chance of unplanned downtime plus the newly developed tooth system involves easier and fewer point changes. All the system values also provide increased sustainability over previous systems.

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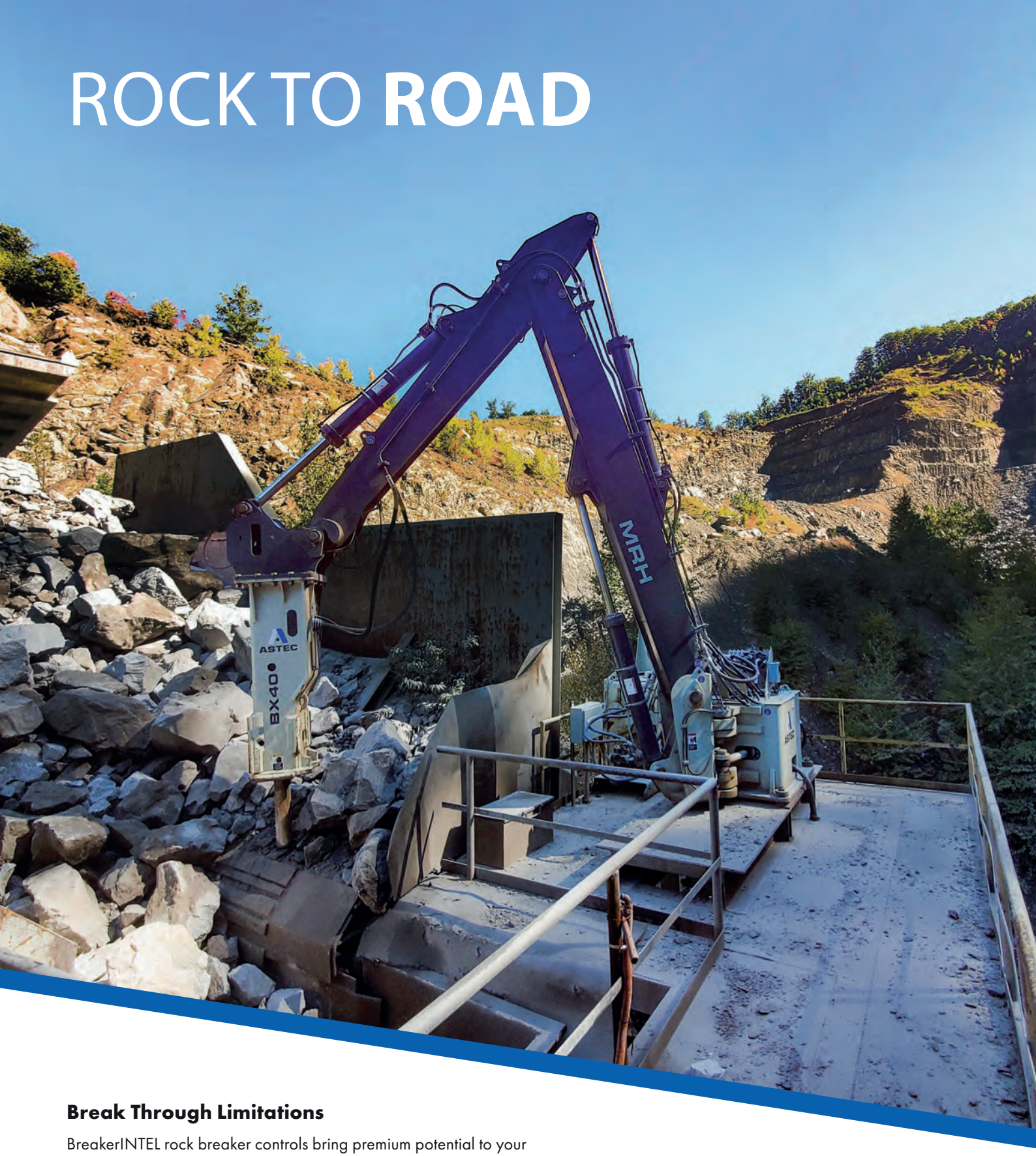

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Komatsu highlights decarbonisation, productivity & safe maintenance

To get some insight into the large mining excavator market, ***IM*** spoke to Dr Thomas Jordan, Head of Marketing & Sales Support at **Komatsu** Germany – Mining Division, which manufactures the complete range of hydraulic mining excavators in both electric and diesel drive configuration from 300 t PC3000 to 800 t PC8000 at its manufacturing facility in Düsseldorf. He commented: "For hydraulic mining excavators, there are three major topics that are currently important to our mining customers and therefore also for us. These are first decarbonisation, second efficiency & productivity; and third the elimination of live work on the machine."

Starting with decarbonisation, Jordan said: "Our customers have clear emission targets to hit by 2030 and beyond. At Komatsu, we are dedicated to supporting them through strategic partnership, with a particular focus on electrification. We offer electric power options for all our models manufactured in Germany, ranging from the PC3000 to the PC8000. This year marks a significant milestone as we celebrate over four decades of electrified hydraulic mining excavators. Since our inaugural electric mining excavator deliveries in 1983, we've supplied over 260 units, serving our worldwide customer base. Up to now, our electrified machines in the market have accumulated more than 12.5 million operation hours, showcasing our commitment to sustainable and efficient solutions in the mining industry."

Komatsu additionally offers an automated cable drum to optimise cable management and simplify the operation and serviceability of its electric machines. Introduced in the mid-1980s, this feature is available for all excavator models. The system is based on the tension on the cable, and winds it up or down depending on the specific need, eliminating the need for manual intervention by the operator.

Is there a ramp up in electric excavator interest and orders? "The general level of interest has noticeably increased, particularly in markets that have traditionally emphasised conventional diesel machinery – Australia is a noteworthy example of that. Furthermore, in terms of product deliveries, there is an observable growth in the proportion of electrified machines compared to diesel-powered ones. Although the percentage increase is modest, it represents a gradual shift in the market over the last three to five years."

Jordan added that in certain markets there is a great deal of interest in converting from diesel to electric during the shovel life. "At Komatsu, we offer solutions that exemplify our commitment to sustainability. A notable example occurred in 2019 when we undertook a significant project involving the conversion of three PC8000 units to

A PC8000 converted from diesel to electric in Zambia

electric drive at a copper mine in Zambia. Since the conversion, each unit has accumulated close to 30,000 operating hours. Subsequently, the customer decided to invest in further new electric machines. For many customers, conversion is likely to be a first step – a starting point before investing in new equipment. This approach allows them to explore the benefits of an electric drive while giving their machine a second life with a lower TCO. In two ways it is a win-win situation: reducing operational expenses as well as contributing to a much lower carbon footprint."

He adds: "Our high-quality steel structure is made in-house and uniquely robust. We therefore suggest that our customers consider converting to an electric drive when undertaking a major midlife overhaul. The benefit here is that most of the main structure, undercarriage and boom plus attachment can remain in place and only the diesel specific parts need to be replaced. In practice, the diesel engine is removed and instead an electric motor is installed. This goes hand in hand with further changes to controllers and harnesses, as well as replacing the fuel tank for the switch cabinet, enabling a second life of the machine."

Has there also been more interest in electric excavators in metallic mining whereas in the past, demand was dominated by the coal industry, with these open-cast mines already having electric infrastructure in place? "Definitely, we are registering increased interest now in hard rock applications, across copper and iron ore particularly. In view of the growing general interest in electrification of those industries, this represents a great opportunity. This interest is particularly pronounced in cases where customers have the capability to procure renewable energy from various sources. Additionally, in certain regions, the electrification trend is being propelled by regulatory permitting requirements, as exemplified in the Scandinavian countries."

On efficiency and productivity, the –11 variants are available for all our machines ranging from PC3000 to PC8000, which feature safety improvements, such as the improved access and egress system with a 45-degree access ladder, plus two emergency egresses on the cabin- and machinery house-side of the machine. Komatsu also incorporated the latest EMESRT findings to enhance serviceability and safety during maintenance; these machines are also equipped with the KomVision 360-degree birds-eye view of the machine.

"Beyond all that, the –11 technology allows for performance improvements such as higher availability thanks to a simplified electrical schematic – a lean electric system with Komatsu pumps and controllers to minimise the number of components and therefore downtime. We also have the option to extend machine settings via the Komtrax Plus monitor inside the cabin. Our Komtrax Plus upgrade enriches the data and machine status visualisation in the cabin and offers storage of real time machine monitoring data. You can assess downtime information and R&M status to maximise product & component life."

Another digitalisation option includes a payload meter system to improve the digging process. Finally, a further -11 focus is the reduction of cost per tonne through a more advanced and lean electric system as well as fuel efficiency improvements for diesel-driven machines through the latest Tier 4 Final-certified engines.

On to elimination of live work – this refers to taking service engineers out of higher risk operations and situations. One example of that is the recently introduced Komatsu Valve Adjustment Device (K-VAD) which facilitates the safe and secure adjustment of main and secondary relief valves on hydraulic mining excavators. It allows for remote operation from within the operator cabin, eliminating the need for service engineers to work next to high-pressure areas. This increases safety in the workplace and prevents work on the running machine in the high-pressure area. It can be operated via Wi-Fi or via the 7-in touchscreen. The set includes everything needed for valve adjustment: pressure sensors, adjustment motors with tool heads and allen keys. The device can be operated by laptop, tablet, or smartphone. It enables the control of up to six tool heads and displaying up to four pressures. Moreover, the engine power check can be carried out with the K-VAD tool.

HCM on the EX-7 series & ultra durable boom project

With more than 100 years of experience across its group companies, **Hitachi Construction Machinery** is certainly a leading industry pioneer for mining excavators, evidenced by its EX-7 series that runs all the way up to the 800 t EX8000-7, with these models it says showcasing HCM's leading edge with innovative technologies and proven, trusted design. "With advanced technology at its core, Hitachi Construction Machinery's EX-7 excavator is engineered to tackle the most demanding jobs in 24/7 operations. Reliable digging power and a performance-focused front attachment design give the capability to deliver consistent results. The EX-7 models feature energy-optimising solutions, including electronically controlled hydraulic pumps, optimised cooling package, enhanced hydraulic circuits, and a choice of emission configurations to meet regulatory requirements, all combining to help operations minimise costs and maximise productivity."

The EX-7 excavators also feature ConSite Mine, a set of Hitachi technologies that bring the Industrial Internet of Things to mining sites around the world. These machines can connect to online servers which collect valuable data and turn it into actionable insights, to help customers optimise the safety, production and efficiency of their operations. ConSite Mine performs round-the-clock remote monitoring of compatible ultra-large hydraulic excavators and rigid dump trucks and provides two types of status reports to the customer's maintenance staff or to service personnel at distributors. The reports are sent via email or the 'ConSite Mine Shot' smartphone app. The 'Monthly Report' provides updates on the machinery's operational condition each month, while the 'Alarm Report' notifies personnel when any abnormalities are detected by the various sensors installed on the machinery that may require immediate attention.

The entire EX-7 series lineup is also available in cable electric. HCM told ***IM***: "Many of the leading mining customers are aiming for net zero emissions by 2050, and plan to decarbonise in stages. The trend to strive for zero-emission at mining sites is accelerating especially among major mining companies, and the shift to EVs is expected to accelerate further going forward. Under such a market circumstance, we offer a full lineup of cable electric mining excavators ranging from 190 to 800 t."

EX-7 diesel engine excavators have the choice of MTU or Cummins brand engines, including the choice of emission configurations to meet regulatory requirements, combined with new electronically controlled hydraulic pumps, optimised cooling package and enhanced hydraulic circuits, to provide unparalleled performance and efficiency.

In April 2023, HCM announced the development of an enhanced boom and arm for its range of ultra-large hydraulic excavators, the improved durability of which it says will extend service life 1 by 1.5 times compared to previous models. Durability has been improved by expanding the applicability of steel castings to the boom and arm connecting part and is applicable to backhoe front excavators. Serviceability has also been improved by equipping the boom with an access hole that can be opened and closed with a bolt for easier inspection. Welding strength and part of the thickness of the boom and arm have also been reinforced. As a result, customers will enjoy reduced repair downtime of their mining equipment and lower maintenance costs too.

With advanced technology at its core, Hitachi Construction Machinery's EX-7 excavators, like this EX8000-7, are engineered to tackle the most demanding jobs in 24/7 operations

The newly designed boom and arm will be applied as standard equipment to the EX5600-7 backhoe excavator (operating weight of 550 t), before being gradually expanded to other applicable excavator models. Durability tests have been underway since August 2023, prior to standard application, under actual operation loads at Brockman 4 iron ore mine in the Pilbara region of Western Australia, operated by mining giant Rio Tinto.

HCM told ***IM***: "The durability tests are carried out over a period of approximately seven years, from August 2023 to 2030. The tests will verify whether the boom and arm of ultra-large hydraulic excavators can maintain the expected durability under actual operating conditions. The boom and arm of ultra-large hydraulic excavators are generally checked on a daily basis by visual inspection."

It adds: "Through collaboration with Rio Tinto, the accumulated load on the ultra-large hydraulic excavator's boom and arm is monitored using Load Index, one of the functions of ConSite Mine, Hitachi Construction Machinery's service solution for mining sites. The accumulated load applied to the welded structure of the boom and arm while

digging can be analysed via the machine's sensors and AI to predict the possibility of anomalies, such as stress fractures. Durning the durability tests, our engineers will visit the site once a year to detect any possible internal damage."

Also on ConSite Mine, a function to detect and inform the failure possibility of hydraulic pumps of ultra-large hydraulic excavators began operation in November 2022. HCM told ***IM***: "ConSite OIL, which has a high reputation for medium- and small-sized construction equipment, has been applied to ultra-large hydraulic excavators since September 2023. By utilising sensors which monitor the excavator's hydraulic and other oils, the condition of these oils and associated components can be evaluated. Since maintenance, inspection and replacement of parts can be implemented according to conditions of the parts and components, the excavators are kept in a good working condition, which contributes to stable operation of mines."

Caterpillar's power agnostic next generation

Caterpillar told ***IM*** it is advancing with its power agnostic shovel strategy. All of its next generation diesel machines, which are already in the market via the next gen 6060, are designed to convert to cable electric operation. For these models it emphasises the importance of the electronic architecture that is designed for future updates. "The development of next generation machines follows a development approach focused on innovation and continuous improvement. Recognising that sustainability and carbon footprint are key focus areas for miners today, next generation shovel innovation is closely tied to mining companies' energy transitions goals."

"The loading tool is an important piece of many of our customers' carbon reduction journey and we have already partnered with some of them on these efforts," says Paul Taylor, HMS Value Stream Manager. "The advantage we have is that we already have a solution for them."

The 6060 hydraulic mining shovel features an exchangeable power module that lets you convert from diesel to electric power, improving efficiency in certain applications. This process is quick and easy for simplified service and reduced downtime, and can be performed at any time — so you can make the switch when your operation is ready. They are basically the same machine except for the power module and upper counterweight, which can even be swapped years down the road.

Caterpillar Engineering Manager Sean Johnson: "You can start out with diesel, and as your mine site grows its electric infrastructure, you could convert that to an electric machine, replacing the two diesel engines with two electric motors."

Current diesel-powered machines are also delivering sustainability benefits through efficiency improvements that reduce fuel burn. For example, the next generation 6060 reduces fuel usage up to 15%. "Hydraulic optimisation is really helping right now in that space," says Johnson.

Looking at the future of mining, Lane Hobenshield, HMS Technical Steward, sees advancements allowing customers to select smaller or fewer loading and hauling units to deliver the same production with a smaller environmental footprint at a lower cost.

"An increase in annual production combined with mining truck advancements will significantly affect the loading and hauling system cost-per-ton equation, which may differ from historic recommendations," says Hobenshield. "Given our full range of loading and hauling equipment and cost simulation tools, Caterpillar can work with customers to determine what is right for their mine site."

On attachments, both Face Shovel and Backhoe configurations are available for the 6030, 6040, and 6060. Cat says demand is split worldwide. "FS and BH have the same hydraulic oil pressure, oil flow, engine power, and bucket volume, resulting in the same productivity, so application

conditions drive the productivity and decision between choosing an FS or BH model. It depends on various factors, including material type, blast quality, bench height, the mine plan, and customer/operator preference. FS attachments are generally recommended for tough digging and high benches, while a BH attachment is recommended for soft overburden and low bench heights."

Immersive on loader operator performance with AHS

The introduction of autonomous haulage broadened the task variety and system knowledge required by loader equipment operators. The industry has found the cross-skilling of loader operators to manage an AHS area, while also being proficient at digging and loading, can be time consuming and must be done right to avoid any unintended negative consequences. One of the most proven methods to develop AHS workforces has been advanced equipment simulation. **Immersive Technologies** told ***IM*** it was first to respond to this need with a training solution that integrated high fidelity simulation equipped with simulated control systems for AHS operations, paired with interactive virtual classroom lessons. The industry first training solution was deployed at Codelco's Gabriela mine in 2014. Fast forward to 2024 and Immersive Technologies continues to be the leading autonomous training solution provider with high fidelity training solutions deployed at 28 of the largest autonomous mines in the word, including training installations for customers who run Cat Command for hauling and Komatsu FrontRunner AHS. So what is new in the autonomous training space? Immersive told ***IM***: "As time progressed this training methodology has gained wide acceptance, what once was a solution primarily for loader operators has now expanded into any operator role that interacts with autonomous haulage. For example, in a mine environment there will be light vehicles, dozers, graders and wheel loaders which are operated by humans to perform a mining task, in conjunction to managing or interacting with autonomous haulage. Today, most autonomous haulage mines include multiple machines within their simulation training program, and many of the training objectives focus on how these roles interact with the loading location and loader operator." Common training objectives that happen at the load location include beyond production loading itself, load location situational awareness, maintaining the virtual model of the mine, responding to exceptional circumstances plus load location maintenance & cleanup. It also includes haul road & pit floor maintenance, navigating entry and exit of an area, upskilling large workforces efficiently and switching trucks from autonomous to manned operation. "Immersive Technologies continually collects and listens to the voice of our mining customers to identify and overcome new training challenges.

Immersive Technologies continues to be the leading autonomous training solution provider with high fidelity training solutions deployed at 28 of the largest autonomous mines

Builder X leads remote control shovel charge

It is well known that the remote operation of large mining shovels is something that the major miners want – it is a natural progression as part of taking operators out of hazardous in-pit working locations and conditions, plus in mines that already have autonomous trucks as well as autonomous drills, the shovel and excavator operators are the only primary fleet operators left in the field, not including of course maintenance crews plus the ancillary fleet.

IM has reported widely on this topic, including progress being made by Caterpillar, Komatsu, Liebherr and Hitachi on commercial OEM-led teleremote shovel offerings as well as some real world examples from third party technologies companies like RCT (now part of Epiroc) and HLS Hard-Line (now part of Hexagon).

Over in China, a number of hydraulic excavators and large electric rope shovels have already been converted to teleoperation; many of them using technology and systems supplied by Builder [X] Robotics aka **Builder X**, a Beijing-based company led by Shaolong Sui, Founder and CEO. The mines concerned tend to be some of the largest in the country and those most focused on intelligent and smart operations; plus they tend to also be running or testing autonomous mining trucks as well.

Looking at 2023 alone, a good example is from CHN Energy's Heidaigou coal mine in the Zhungeer Coalfield. On March 2, 2023, the mine and its auxilliary coal preparation plant passed the acceptance inspection for China's first group of intelligent demonstration coal mines. As part of that it has built a 5G network that covers the office area and the unmanned operation area in the pit, plus established a 140G optical transmission network system that realises high-speed communication with video surveillance devices.

Builder X converted a XCMG 700 t class XE7000 hydraulic backhoe excavator – to use its Tele+AI Operation System. The system provided also incorporates intelligent features such as pedestrian detection, bucket teeth detection, and posture monitoring, effectively mitigating the impact of harsh environmental conditions on operations. Following training involving 97 trucks, operators swiftly adapted to the remote operating mode, with loading efficiency approaching on-site loading efficiency at approximately 220 seconds per truck. Heidaigou operates autonomous trucks including retrofitted Komatsu 930Es using WAYTOUS technology.

Also in 2023, at a high altitude copper mine at 5,600 m with temperatures as low as -40°C, Builder X converted a large TYHI TZ WK-35C mining shovel for teleremote operation. The operation has not been named by Builder X for confidentiality reasons – but from the shovel and altitude concerned can be identified as Zijin Mining's Julong mine – plus an image supplied shows the shovel remotely loading an autonomous NHL NTE240BAT electric drive truck; Julong began autonomous truck fleet planning and installation with TAGE Idriver back in 2021.

The tech takes operators away from a snowy or often dusty environment where the altitude also requires operators to have to use supplementary oxygen at times. Again using a 5G network, the Builder X system offers auto-loading but also AI including pedestrian detection, anti-collision warning, and high-pressure flameout/shutdown. Builder X says it has improved work efficiency, with operators completing a full truck load within 4 minutes. Plus it has ensured operator safety and significantly enhanced job satisfaction as well as mitigated the challenge of labour recruitment difficulties at the mine.

Moving back to coal, and SPIC's Huolinhe coal mine in Inner Mongolia ranks among the five largest open-pit coal mines in China and experiences long, extremely cold winters with temperatures dropping to -40°C. It also faces hot summers with frequent rainfall, often accompanied by strong winds and dust storms. In 2022, Builder X installed a teleremote system on a TYHI WK-12 rope shovel, again running on 5G and featuring pedestrian detection, auto-loading, and remote flameout/shutdown.

The system was swiftly put into operation, showcasing impressive loading efficiency of one truck every 4-5 minutes initially. Over time, this efficiency averaged at 3 minutes per truck, even during night operations, becoming the standard in the mine's routine operations. In 2022, CCTV10 featured a report on the remote intelligent control electric shovel at Huolinhe. In 2023, due to the positive operational and societal impact, the mine made a repeat purchase, upgrading to the Tele+AI Operation System on another WK-12C electric shovel. Huolinhe is well known as an innovative operation, using XEMC and NHL autonomous trucks as well as having pioneered the use of an all battery rigid mining truck in China, a converted XEMC SF31904 AC.

A similar system was installed for another top five coal mines in China in Inner Mongolia – conversion of TZ WK-12 shovels at CHN Energy (Yanbao Energy)'s Yuanbaoshan coal mine; with additional pedestrian detection, real-time monitoring and six-screen splicing. The mine also operates autonomous trucks and has established a dedicated dispatch command centre.

Given the challenging geological conditions of loose soil and potential groundwater seepage at Yuanbaoshan, vehicles commuting to the site leave deep ruts on the ground, reducing travel efficiency. The adoption of remote intelligent control for shovels eliminates the need for operators to commute to the site, requiring only periodic on-site maintenance by repair personnel. This extension of operational duration in the mining area ensures that the efficiency and output of electric shovels are no longer impacted by traffic issues.

Xilinhe coal mine embarked on a technological transformation in 2022, with a focus on automation, integration, intelligence, and unmanned operations. It now utilises Builder X's Tele+AI Operation System, incorporating intelligent features such as pedestrian recognition and one-click reset on four electric shovels. This involves the use of technologies like laser radar, line control upgrades, and ultra-low latency systems.

Other coal mines having shovels converted for teleoperation by Builder X include Tianchi Energy's South coal mine. In early 2022, in parallel with the deployment of a large fleet of autonomous mining trucks by Eacon Mining, a collaboration between Eacon and Builder X, saw a Caterpillar 349 backhoe hydraulic excavator converted to remote operation. Selected AI functions include a bucket depth indicator, bucket teeth detection, pedestrian detection and large block recognition.

Moving to iron ore and in 2021, Baotao Steel's Baiyun iron mine (also called Bayan Obo) began implementing an intelligent remote control transformation, utilising the Builder X Tele+AI operation system to retrofit equipment such as TZ WK-10 electric shovels and XCMG XE3000 excavators. This enables remote control operations for various types of equipment, ensuring on-site operational safety. Additionally, the application of intelligent AI functions such as posture monitoring, anti-collision warnings, and data monitoring enhances operational efficiency. By 2023, the mining area has completed the construction of a smart control centre building and has repeatedly purchased the Tele+AI operation system, upgrading various equipment like WK-20 and WK-4C shovels, PLK4500 dozers and KY-310 drilling rigs. Bayan Obo also has a well established autonomous truck fleet – NHL NTE brand electric drive trucks using TAGE Idriver's system.

Finally, since the beginning of 2020, Builder X has now collaborated with Japanese partners ▶

for nearly three years, continuously upgrading and iterating its products to enhance installation convenience, interface user-friendliness, and the practicality of AI-assisted features. These efforts have significantly strengthened the competitiveness of Builder X's Tele+AI Operation System in the Japanese market.

In April 2023, representatives from Sumitomo Corporation and Obayashi Corporation visited Builder X's office, and signed a trilateral strategic cooperation agreement, jointly promoting the application of the Tele+AI Operation System in Japan. This event marks a significant milestone in the partnership between the three companies. Starting from July 2023, the Japanese partners initiated Proof of Concept (POC) assessments for different brands of excavators, including Caterpillar, Komatsu, Sumitomo, and Hitachi, in various scenarios such as mining, ports, and factories.

The Tele+AI Operation System from Builder X is leading the remote control shovel charge in China

The result is the Advanced Equipment Simulator and Digital Learning products are continually enhanced with new features. Recently, for example, new capability has been added to AHS traffic interactions, escort procedures, spotting equipment and managing hazard and keep out zones."

MTG's new VEEMET family

Looking at ground engaging tools (GET), launched in 2023 the new **MTG Systems** VEEMET product family it says has been developed as a successor to the renowned STARMET system further improving performance and user-friendliness. "Incorporating various optimisations and unique novelties makes it one of the most advanced systems for the mining, quarrying and construction industry. Its wide portfolio of 10 sizes, ranging from 20 to 500, has especially been designed for plate lip excavators and loaders of 20-250 t as well as smaller draglines." The market introduction started with the bigger mining sizes 500, 250 and 190 followed stepwise by the medium to smaller sizes.

MTG adds: "Enhanced stability, optimised locking and improved penetration are, amongst many, the most important benefits. Additionally, two unique novelties underline the progressiveness of the VEEMET system: A tooth-integrated QR-code provides up-to-date technical information and the compatibility of the bigger mining sizes (≥190) with MTG's GET DETECTION system allows a digital GET monitoring for even more safety and productivity."

The standout key feature is the V-shaped fitting which gives the system its name (VEE = V-shaped). In combination with an 80% larger nose contact area, this fitting strongly increases stability, reducing plastic deformation. Another important feature is the optimised locking. Assembly and disassembly have never been as easy, quick, and safe. Tooth change-outs are possible in only two steps and reinforced pins with more contact area reduce the possibility of pin bending by 52%. IM

Featuring an industry-first curved thread design, Sandvik's new CT55 and CT67 top hammer tool systems are the most advanced the company has launched

Premium top hammers

Sandvik Mining & Rock Solutions through Sandvik Rock Tools sees itself as a first mover and premium innovator in rock tools, and has put these words into action again in recent years, as Paul Moore reports

In the past few years, Sandvik has made the most significant additions to its top hammer tools and technologies line up arguably in over two decades – including a complete optimisation of its Sandvik Alpha™ thread system for underground, plus the all new CT55 and CT67 top hammer tools for surface and underground drilling. Not only that but its revolutionary Autobit for automated top hammer drilling, first introduced in 2021, has really been making its presence felt in the market, thanks to the use of patented PowerCarbide® inserts.

On a recent visit to the Sandvik Rock Tools HQ in Sandviken, ***IM*** Editorial Director Paul Moore had the chance to sit down with the top hammer product line VP as well as the product managers for both the surface and underground top hammer tools to discuss these developments in detail – why they are significant and why there are a differentiator for Sandvik.

A premium position

We started by talking to Anders Brungs, Vice President Product Line Top Hammer at Sandvik, about the group's well earned premium market position and role. Brungs: "We are first and foremost I would say a premium tools supplier – by that we mean that we really have unique products that are patented, that bring significant added value to the customer, but also that we devote a lot of investment and time into our R&D. On the patent point, we know we are a leader as we have the most patents of any of the major rock tools suppliers globally, covering design elements, how to reduce stresses, geometry and even the tungsten carbide formulations themselves. On value to the customer this could be increased productivity or improved hole straightness, greater safety, less fuel consumption, or a combination of these."

Brungs also pointed out how far the industry has come in terms of technology. "The standard bit and rod products and designs still being used date back to the 1950s – with these you just can't get performance improvements. These were developed for pneumatic drill rigs running on 8 kW of power – today's rigs use 30 kW."

But what about those customers that are more initial cost focused, regarding tools as more of a commodity? He responded: "In any market you will have customers that are price-based buyers. We of course identify who those are and either leave those to competitors or we train them in better strategies – maybe they are not using the products correctly, or they are not using the right products, or maybe they are not understanding the full scale of costs. We have seen many customers over the years that have gone from being focused on price per piece to gradually being able to see the value of the more engineering products." And it is also the case that differences can apply from operation to operation sense – there are very few mining companies that have global supply agreements in relation to the rock tools that they use.

Do the customers get involved in product development? Brungs: "Some do, yes. We have down a huge amount of new underground product trials in many Swedish mines, as an example, and many tests with them over the years. In many ways these Swedish mines represent a base line of technology performance for our products and of course some of the operations are quite accessible to us here in Sweden. In many cases we even know the particular drillers personally which all contributes to the quality of test results. We also do a huge amount of testing with Swedish surface contractors as well as tunnelling contractors. But much further afield we have also done a lot of work with leading mining contractors in Australia on underground mining."

Alpha innovation in action

We then spoke to Robert Grandin, Product Manager for Top Hammer Underground Tools about Sandvik Alpha™ developments. This is a thread in the bit connection that is mainly used in mine and tunnel development operations ie with drill jumbos. It is optimised for 45 mm drilling which is the industry standard in many of the main mining markets.

Grandin: "We have had our Sandvik Alpha™ 330 system for a long time – over two decades – and while it is a fairly simple product, it has many outstanding features. It was truly groundbreaking for the time when it was developed and what could be done back then. With today's tooling and treatment machinery combined with simulation, we are able to make big steps forward in product optimisation. We have gone from trial and error to optimisation by computing power first. We have developed a different Sandvik Alpha™ thread profile – so it is in fact asymmetric, meaning that the flank angles are different on the front and back. This hugely reduces the stress area where we have contact, as we have a contact flank in the thread where we tighten the thread, and that is where you develop the most heat and friction, so that is therefore where you see damage and breakage most often."

He adds: "Another weak point in the connection is the female connection in the bit – this sets a limit in how big the male thread can be in relation to the female. So we have made improvements internally as well by strengthening the guide section around the tightening flank to add fatigue strength, plus we have reduced the stress levels on the bit, which was then an enabler for us to increase the rod size in terms of diameter by about 1 mm, plus there is now a bigger flushing hole as well. And, last but not least, we have also made the product easier to uncouple with the pitch and flank angles that we have used."

All of the mentioned Sandvik Alpha™ changes mean a much longer service life. But Grandin says what customers have also really appreciated is this ease of uncoupling. "Why? Because this is something that drillers notice on the very first shift." The uncoupling itself is not yet automated but Grandin said that this is the way things will go. "We already have an automated bit changer. Rod uncoupling I would say today is semi-automated but I would fully expect full

Fredrik Björk, Product Manager for Top Hammer Surface Tools; Right: Robert Grandin, Product Manager for Top Hammer Underground Tools

automation in the next four to five years."

Some of the plus points from the previously available Sandvik Alpha™ 330 have been carried forward – the short thread and the guide behind it. The new Alpha product – Sandvik Alpha™ 340 – began rollout in the market in late 2022. It is applicable to rod lengths of 2.4-6.4 m; bit sizes of 43-76 mm; and reaming bit sizes of 102-127 mm. Then you have Sandvik Alpha™ 360 which has the same design changes but is larger – it combines a robust short thread with a sturdy guide system. This increases resistance to bending stresses, improves bit guidance and ensures effective energy transfer.

On market rollout he commented: "Considering that we are a major player and that Sandvik Alpha™ 330 has been our flagship product pretty much sold everywhere, it has been and is a huge project to upgrade all of these customers to the new concept. And because of the degree of higher performance and service life, Sandvik Alpha™ 330 is being completely replaced. We started this process in November 2022 and by June 2023 had reached halfway – to date this has nearly been completed. All these customers are already implementing it at site level. And while we expected some teething issues, so far we have actually had none, which is quite something for such a new product and solution. We have had at least a 30% longer service life versus competitor solutions and on average 15-20% versus Sandvik Alpha™ 330. Increased service life results in increased productivity and reduced cost per metre advanced; plus of course we have had much higher customer satisfaction because it is so much easier to use for operators."

Autobit for the masses

The new thread concept goes hand in hand with improved drill bits. High performance PowerCarbide® grades are now more widely available in the standard bit assortment, with many bits having received design upgrades with more gauge angles or larger buttons for increased robustness.

But the most significant product here is Autobit. Brungs: "Automation is something that everyone is interested in. What we saw was that drilling over shift changes using autonomous drilling technology in medium abrasive ground, that the previous bits were not going to last an entire shift change. This is because the level of wear on the carbide starts to slow down drilling significantly and you need to change the bit. And actually, auto bit changers are not popular with customers as they see it as another machine with fine mechanics they need to maintain underground in often wet and challenging conditions."

Grandin adds: "At Sandvik, we said OK, lets develop at bit which you can use for a longer period of time. We engineered the design, looking at the fundamentals – why do bits wear out, how do they wear and what stops them drilling? We changed the button design including the geometry around the buttons and not only that but also the carbide grade. In simple terms we delayed all the factors that start to make bit functionality drop off. We also reduced the amount of excess steel that can come into contact with the rock by making the insert protrude more to maximise the length of time carbide is in play. And in other areas we carved out a recess in the steel to enhance this even more."

Autobit was designed to work with autonomous drilling and this is where it started in the market but in fact it has now been deployed in many non autonomous drilling situations as well simply due to its performance.

Grandin continues: "All the things I have described are pretty attractive in non autonomous as well as autonomous drilling. The design and reduced steel area means you can drill the carbide inserts to near flat and the bit will still work. And we are utilising PowerCarbide® – while competitors have made investments in PCD technology, it comes with a much higher cost, and our unique carbide grades deliver similar performance because they drill with 30% higher drill speed. Not only that but PCD as a material does not allow you to do some of the things we have done, notably the greater insert protrusion and aggressive geometry, because by nature PCD is very sensitive to breakages."

Autobit comes with a new, innovative bit design, which combines a strong gauge row, fully ballistic button profile and carved-out front design

He says the market for Autobit has grown exponentially since Sandvik launched it. "There is no question it has the potential to become the dominant solution in the market – you could almost rename it The Bit not just Autobit! There is no real reason to use anything else. We are seeing it for example being used in African mines that have no autonomous drills but appreciate the penetration rate and longer service life."

In terms of use strategy in those mines that do use autonomous drilling, the idea is that when the shift is over, then you put on a new Autobit for autonomous drilling. Then you regrind it and drill it during the manual drilling shift. The grinding interval declines after several regrinds but that is all relative – the overall life improvement is still very high. This all reflects the fact that many mines operate drilling manually during normal shifts and only use autonomous mode between shifts – they are not running their drills autonomously all the time.

While Autobit was first rolled out for autonomous production ie fan drilling in stopes, in late 2023, it was also introduced into autonomous development drilling applications.

The power of PowerCarbide®

We also talked to Petter Bengtsson, Director Marketing & Communications – Rock Tools Division about the important role played by Sandvik's in-house tungsten carbide production facility in Västberga (which was also visited by ***IM*** and will also be the subject of a follow up article): "We are really grateful for Västberga and the carbide R&D we have there – without its innovations, the new Autobit design would just not be feasible in harder rocks. The carbide development is really an enabler to us on the rock tools teams. Competitors by comparison have to buy standard carbide products on the open market. New carbide grades are traditionally made by changing the grain size and binder used. You want to achieve maximum hardness along with maximum toughness. We have moved away from the standard XT48 which have similar hardness throughout the body of the insert

towards our new grades like GC81 (Gradient Carbide) and SH70 (Self-Hardening), which are based on improved knowledge about the wear of the drill bit in different types of rock."

GC81 is developed for abrasive ground conditions with high silica levels in the rock. A new, unique method makes it possible to produce buttons that are wear-resistant on the outside, while the centre provides a toughness that pushes the service life and grinding intervals even further. SH70 is a grade with homogeneous properties throughout the material. Sandvik calls it 'self-hardening' because it has the ability to get more wear resistant as you drill with it, due to enhanced deformation hardening. The surface hardness is continuously 'refilled', which means that the hard top never wears off. The hardening effect is greatest in hard and competent ground.

So what proportion of Sandvik bits are using these new grades today? Bengtsson: "Item by item, we are phasing out the standard XT48 grade across all of our surface and underground bits. This involves SH70 on Autobit and GC81 on other bit ranges. And it isn't limited to top hammer either – our DTH and rotary bits are also benefitting from new PowerCarbide® grades. The time taken just relates to ramping up production of the new carbide grades, getting through existing bit stocks on the customer side, switching over on our side in terms of the button production and incorporation of those into the bits, but also the sheer amount of bit products that need to be switched over such as the Retrac ranges. As well as the three to four months lead time that we give to ship to customers in many mining areas."

A new thread following

Moving to other developments for surface tools, at *CONEXPO 2023*, Sandvik had a soft launch of the CT55 and CT67, whose development first began with a Sandvik engineer saying they wanted to set out to make the 'perfect thread.' These curved thread systems are designed for surface mining and quarrying, as well as longhole drilling underground. These systems accommodate higher drilling power than the standard ones and feature a curved profile that reduces stress levels strategically while optimising the product for fatigue strength.

Fredrik Björk, Product Manager for Top Hammer Surface Tools, told ***IM***: "Both the new threads are built on the same technical platforms. The main reasoning behind their development was that on the typical surface crawler top hammer rigs, there was a lot of power that could not be used realistically with our standard T51 and GT60 rod systems due to too much heat limiting service life. Or put another way as our rigs got more powerful, we had to step up the drill string as well to match their performance. With CT55 and CT67 we have achieved a higher penetration rate, and good flushing performance. They allow more efficient energy transfer and have a stiff and strong connection."

The curved thread has a bigger cross-section where it is needed, reducing stress levels, plus a more robust coupling system, allowing for easier coupling and uncoupling with double thread entrances and minimal rattling. Rattling refers to a process used to uncouple drill rods using high pressure percussion for some seconds to get them to come loose. With CT you can reduce this rattling time to 0.5 to 1 second and even saving a few seconds of rattling is critical for service life of the rods.

Björk adds: "The design of the CT (Curved Threads) means the energy is transferred from the shoulder to the female end. This means we can handle higher percussion forces. The curved thread has also allowed us to further strengthen the male and female where needed. Traditionally on top hammer threads all the wear is at the beginning and the end with the middle untouched – with the new threads the wear is much more evened out. All the new design features were run through hundreds of simulations as well as on our test rig here at Sandviken, using different pitches and combinations. Everything is also now protected by a set of new patents as well."

Thanks to the stiff coupling Sandvik Rock Tools has also dared to also increase the dimensions – with the T51 thread, it is 52 mm with a 21.5 mm hole – its replacement the CT55 has gone up to 56 mm and opened up the hole also to 28.5 mm. "So with just a small increase in area, which is crucial as there needs to be a balance with the hammer, we have 27% higher stiffness ie it doesn't bend meaning higher percussion and feed force. Its the same story with the GT60 and CT67, its replacement where you have a 45% increase in stiffness. Better contact with rock means better penetration."

The formal global launch of the CT55 and CT67 took place in November 2023, for surface bench drilling but also for underground longhole drilling as well, for example underground instead of replacing the GT60, the CT67 replaces the ST68. Björk: "Our new CT system radically increases the fatigue strength and we've also seen 30% longer tool life together with better hole precision in our product evaluation tests with early-adopting customers. This is a fully optimised system that includes the drill rig, the rock drill and the rock tool. The CT system also brings out the full potential of Ranger™ DXi and Pantera™ DPi rigs, especially the powerful Ranger DX900i and Pantera DP1500i."

As with the Sandvik Alpha™ 330, the GT60 in particular, launched over 20 years ago, is used very widely in mining today, so the phase in process of the new CT threads will take some time. "The results again are impressive – a productivity increase of 15% conservatively as we have also seen much higher numbers in tests. Extensive use on our own rigs, from which we get very good data collection from the onboard SanRemo Mobile system, has shown we drill faster per metre and per hour. That means we are also reducing fuel consumption per drilled metre by about 15%. Plus it means a much better service life on rods and shanks of at least 30%."

What is the value for a typical small mine or quarry or for their contractor? "With the same rig for the same time and with the same operator a contractor can invoice a significant number of additional metres drilled. Plus they are saving on fuel too. And this is based on one shift. The upside and savings in mining for 24/7 operations for presplit and contour drilling will be higher again. And for an owner operated drill fleet it means a better bottom line. Drilling metres faster and using less fuel to drill them also makes for a compelling sustainability argument as well." In an example given to ***IM***, using similar rigs for 89 mm holes, using T51 took 16.7 h to drill 1,000 m but CT55 took only 13.6 h. As the fuel use was similar per hour, the fuel saving really adds up.

The CT rods similar to Sandvik Alpha™ also have a bigger flushing hole. Looking at the CT shank, the shoulder is transferring a lot of the energy to the other end, so a bigger flushing hole compensates for that. The team at Sandvik agreed that the CT is such a game changer that it has the potential to boost Sandvik crawler rig sales with customers wanting to go with a Sandvik drill to get the full benefits of the tools. This also reflects the fact that you need to use the Sandvik rig to use CT on surface. As underground production drills have a more universal design it is possible to use CT technology on competitor drill rigs as well, as long as you are using the whole Sandvik drill string. Going forward, Sandvik is looking at smaller CT dimensions as well.

Finally, also worth a mention is the complete top hammer drilling system that is directly aimed as a alternative to DTH in certain applications which Sandvik refers to as Top Hammer XL – it expands the hole size range of top hammer drilling up to 178 mm (7 in). It provides a faster and more fuel-efficient drilling method that can considerably reduce CO_2 emissions. The fully optimised drilling system consists of the Pantera™ DP1600i drill rig, RD1840C rock drill and LT90 rock tools. LT90 MF tube rods are developed to convey high energy shock waves with minimal energy loss in the threads.

This solution has proved very effective in hard and competent ground. For softer or fractured material, DTH still has the edge – and Sandvik offers both anyway. One option is also to use Top Hammer XL on the lower, more homogenous lower benches and DTH on the more fractured upper benches in an open pit. IM

Ultimate utilitarians

Paul Moore looks at the world of utility vehicles in mining, which cover an astonishing range of applications and tasks, and are supplied by specialists which are experts in their field

GHH partner UVB has developed a low profile tracked vehicle for use in high gradient (20 degree) development areas

Utility vehicles in mining represent a broad church – normally it is a term used to include anything that isn't related to primary development or production drilling, or the main load and haul fleet. But that includes a vast range of machines, particularly underground, from personnel and tool carriers, to explosives and shotcrete carriers and delivery vehicles, as well as water carts, graders, scissor lifts, scalers and a huge range of other units.

By nature of their applications, safety has always been paramount in this market, but many of the trends and developments that have begun in primary fleets have now filtered down to utility machines – including a greater degree of automation, again tied to safety, but also real time machine monitoring and predictive maintenance, alternative power sources including battery electric, collision avoidance technology and others. This has taken time, as the machines are so diverse in customisation and design, with many specialist OEMs and dealers involved, but it is a definite trend.

MacLean's ML5 set to begin trials in Australia

The global mining vehicle manufacturer **MacLean Engineering** recently celebrated a product launch milestone at its Perth, Australia branch, with the company's first ML5 Multi-Lift mining vehicle having arrived in-country in late 2023 and minesite trials set to take place across 2024. The newest addition to the MacLean Elevated Work Platform product suite is a purpose-built, battery powered alternative to the use of integrated tool carriers ('ITs') in underground operations across Australia. The model is designed for mine services installation and repair work from a certified elevated work platform with a 6.5 m working height and a 4.5 t payload. With best-in-class application versatility and battery electric propulsion, miners and contractors get a diesel-free dividend along with the safety and productivity enhancements that have been engineered into the design from the ground up. The ML5 Multi-Lift was designed expressly for the Australian market, but has application relevance across the mining world, complementing the MacLean Elevated Work Platform product suite - the SL2 and SL3 Scissor Lifts, and the LR3 Boom Lift - as another certified and safe working at heights solution.

MacLean's much anticipated ML5 is entering the Australian market this year

Kovatera's upward trajectory

Starting with flexibility along with robustness, **Kovatera** along with its predecessor brand

Normet's pioneering visions becoming reality

Global utility machine major **Normet** has made some big advances in recent years – and we opted to look at two of them – Charmec Revo, where a remote-controlled robotic arm places the initiating system into the borehole and, in conjunction with the emulsion kit, dispenses emulsion, allowing the operator to remain in a supported tunnel area away from the danger zone. And then the compact Variomec XS family - developed to provide a safe, purpose-built and agile platform for several different transportation applications needed in demanding mining operations. ***IM*** talked with Anssi Mykkänen, Director, Charging Product Line, at Normet; and Herkko Juntunen, Director, Logistics & Utility Product Line.

Normet's Charmec Revo offers a new level of operator safety

Q Can you comment on where Revo has been tested and if real mine trials or commercial deployment are underway?

AM Revo has been comprehensively tested between May and June 2023 in Agnico Eagle's Kittilä mine Finland where Normet's test team successfully charged and blasted ten development faces. In the current year we have conducted a three week testing period in Outokumpu Chrome's Kemi mine where twelve more development faces were remotely charged and successfully blasted. In both the Kittilä and Kemi tests Charmec Revo proved its capabilities as we were working with mine's production schedule without the need for separate test headings. An example of the recognition we have received is from the Kemi Mine Manager and Manager of Ferrochrome, Henri Simpanen: "By systematically enhancing these, we ensure the safety of our employees and take active measures related to exposure control. Through remote and automation measures, we guarantee a safe and manageable work environment for our workforce. The Kemi mine expresses a highly positive attitude towards piloting this automated and mechanised equipment solution, developed by Normet and supported by FORCIT Group. The Kemi mine sees it positively that the development of equipment and methods extends to the improvement of the charging process."

Q What were the biggest challenges to overcome in Revo's development?

AM The biggest challenge to overcome has been robotics development for underground operations where every workplace is different compared to a typical static factory environment for manufacturing robots like as an example in car factories. This has required new ways of thinking but at the same time keeping in mind that solutions need to work reliably in demanding underground environment which might have high water ingress, ambient temperature exceeding 50 degrees, ground temperature exceeding 70 degrees, high salinity levels and so on. All this generates high standards for collision avoidance systems and protection ratings against environmental stress.

Q What has the market response been like to the launch?

AM We have received high interest globally from many key customers and big mining houses. Now we are continuing to develop Charmec Revo technology based on findings in underground testing and the next step is to prove its worth in longer trial type operations. Often, seeing is believing with this type of new and groundbreaking technology and the best way to prove its value is to trial it.

Q Is this part of an eventual roadmap to automate explosives delivery entirely so that the operator does not have to be underground at all?

AM Yes, the grand plan is to move the operator from high-risk areas to reduced risk areas and finally to safe areas meaning an equipment FOPS/ROPS protected air-conditioned cabin or remote safe place permanently out of the work face. This development requires not just charging equipment development but new solutions to initiation (detonator) technologies like semi-wireless and wireless initiation and holistic drill and blast process development to favour a high degree of mechanisation, automation, and remote operation. As Normet we are pursuing new drill and blast processes by discussing and cooperating with our customers, mining houses and contractors as well as explosives developers and suppliers.

Q Related to that do you have active autonomy programs for any of your other machines?

AM We have had a semi-autonomous concrete spraying solution called SmartSpray available in the tunnelling segment for several years. We are actively working in pushing the boundaries of autonomy in several different underground processes.

Minecat is one of the longest established companies offering purpose built and highly mobile utility vehicles dedicated to the underground market – they are very far from being a converted agricultural tractor or on-highway truck.

IM caught up with Sales & Marketing Manager Don King: "The drivetrain we put in our KT200 is not dissimilar to the one used in a small LHD – with Dana axles, planetary hubs, and power shift transmission. It is more like a true piece of mining equipment with a truck body on it – as opposed to an automotive truck that has just been reconfigured for mining. We have found that the larger mining companies in particular that do their due diligence and track things well, have come to see that personnel carriers shouldn't just be seen as consumable items that are disposable. The longevity of our vehicles also means they are more attractive from a sustainability point of view."

On that note he adds: "The average economic life of an automotive style truck used in underground mining is something like three years. By the fourth year they are spending almost the price of a new one just to keep it running – Kovatera has units out there that are 15 years old and still going. We very comfortably quote a lifespan of 10 years but they are lasting far beyond that. So for three or four times the

Q Variomec XS was first launched back in 2021 - how has the concept and the range evolved since then?

HJ Since launch we have put lot of effort into production ramp-up and fine-tuning the product based on customer feedback. Variomec XS is a totally new platform which is also manufactured in our completely new factory in Jaipur, India. The Variomec XS product family is also increasing during 2024, and as such we will have a couple of new logistics applications coming very soon, such as an explosives carrier and an underground ambulance.

Q Can you give any examples of mines that are using these machines?

HJ I cannot give specifics yet but generally we can say that XS machines have been delivered globally and feedback have been very positive. Currently we see lot of interest especially in North America, Asia and Africa. For example, one customer ordered several 11 person underground buses after successful trials and another many crew carriers to replace their Land Cruiser fleet. Thanks to the modular platform design, we are able to make special applications based on customer demand pretty easily, eg one Australian customer needed machines to support cable bolters and we developed a Variomec XS with a special deck and very strong crane for that purpose.

Q The platform is not yet included in the SmartDrive offering - is this because it is aimed more at the conventional and easy maintenance part of the market?

HJ We started out with a Tier 3 diesel platform, because we saw the biggest potential in that market, but SmartDrive and higher emission class versions have been in our scope all the time. Currently, the demand for this size class of BEVs is rising rapidly, probably even faster than for bigger BEV units. I can say that Variomec XS SmartDrive development is ongoing and there will be interesting launches coming in near future.

Q Is it a good option for mines in more challenging parts of the world as well as for contractors?

HJ Yes, Variomec XS is definitely a good option for all underground operations and customers are seeing more benefits in more challenging environments. Many customers are still using surface equipment for lighter transportation purposes – the lifetime and safety level that Variomec XS offers is outstanding compared to those.

lifespan, we offer a much better proposition as regards TCO when you consider both capex and opex. On automotive vehicles the issue is usually with the frames in what is normally a harsh and corrosive environment. We put a 5,000 hour warranty on our frames – most of the automotive frames would not even reach this figure. Ours is not a stamped or box frame – it is designed and manufactured by us for the mining environment. They want something that is safer – we have full wet enclosed brakes, power shift transmission, and a ROPS/FOPS certified cab as opposed to just a canopy. The floor boards are also much thicker than on automotive vehicles, protecting against dangers like rock bolt penetration."

Kovatera and its predecessor brand Minecat have sold well over 1,000 units. Many of these were in tractor configuration but today the KT200 truck and its variants has become the largest seller, because it is so versatile – it can have a crew cab or a regular cab, plus you can have a six or eight person enclosure on the back for a personnel carrier. You can also have a flat deck on the back with a tray and fold down sides for utility and material delivery or it can be a mechanics truck that comes with toolboxes and a crane or welders compressor, scissors decks often used by electrical crews - whatever the requirements are.

If you talk about the still also very in demand

A Kovatera application for material handling based on the Kovatera KM200 tractor

KM200 tractor set up there are even more configurations. “At the front we can supply it with a forklift mast which is used by diamond drilling crews with a personnel carrier on the back. It allows them to be self sufficient in terms of materials like core boxes and drill bits and power units but also get their people home at the end of the shift. The forklift also comes with 4,900 lb capacity loader arms – on that you can put forks or even a small bucket for cleaning up material or you can put a man basket. On the back you can take 3, 5 or 7 people depending on the design which are additional to the three in the cab. You can also put a backhoe on the back which is popular with the man basket on the front as a face prep machine. For ANFO loading we have a rear deck on which we can put ANFO or emulsion pots, again with a man basket on the front. For a development round, it can transport enough explosives.”

How does Kovatera handle sales and has its business also become more global beyond North America? “In Ontario we have direct sales; then dealers cover the rest of North America for us, including Mexico. Beyond that we have other very successful dealers around the world including Drivetrain Power and Propulsion in Australia. Despite Australia being a real stronghold of Land Cruiser vehicles in mining they have managed to make big inroads. Another good example of a growing market is Turkey, where we are represented by Kuvars Makina; and in northern Europe we work with Bergströms Bil & Maskin and will soon be offering models with a Stage V engine.”

King added that Kovatera hasn’t gone to every mining market in the world – that is partly reflective of current production capacity so right now it is focused on serving the markets that it is so far active in. “But it is true to say we have focused on the volume markets and volume customers, and many that have tried our products have now effectively standardised on them or at least made us their primary vendor in this space. I can say we are the main supplier to the Sudbury nickel mining industry, as an example.”

Moving on the zero emissions solutions, how does Kovatera see that panning out after its experience with the battery electric KT200e? “Of course there is a huge interest in battery electric and I think everyone agrees that there will be a transition in mining away from diesel, with the speed of transition depending on where in the world you are talking about. We will be officially launching a new range of battery electric vehicles at *MINExpo 2024* which will include both truck and tractor models and all the key configurations. We will be using standard charging configurations to give customers as much flexibility as possible.”

The battery powered solutions also give further TCO advantages over automotive style light vehicles in mining. Their average lifetime is only three years but then you have battery packs that might last ten years, though obviously depending on how many cycles you charge. “Having a ten year battery in a ten year truck makes a lot more sense. We really think going foward that having a more robust and purpose built vehicle works better for advanced battery packs, given that they are now the most expensive component.”

The KT200e was an electric conversion of the KT200 – whereas these new offerings will be battery electric by design from the ground up. But King said it learned a lot from the KT200e, “and it allowed us to do a lot of pilots and testing as well as discussions with customers on what they were looking for which was all incorporated into the design of the new products.”

Becker’s VOLTER charges up locomotion underground

Moving onto rail-based utility machines, manufacturers of mining equipment are increasingly developing and implementing machines with battery drives and rail is no exception. Locomotives, suspended locomotives, haulage and transport vehicles, and other machines are testament to the development of underground electromobility. New generations of batteries with lithium cells have improved technical and economic effects as well as environmental benefits of electric drives compared to diesel ones.

In particular, battery-powered transport systems are increasingly being used in underground mining. They are a response to the challenges related to: extension of transport and access routes for personnel, an increase in the power of installed machines and devices, increasingly stricter requirements for the working environment, the need to minimise carbon footprint and greenhouse gas emissions, and the need to optimise production costs.

The flagship product of **Becker-Warkop** Sp. z o. o. in this area is the VOLTER monorail battery locomotive. The VOLTER battery locomotive with a friction drive is used to transport people, materials, and equipment during transport works, eg installation and salvage of longwall equipment. The locomotive in a configuration without operator’s cabins is only used for transporting loads.

Each drive unit is equipped with two electric

Becker's VOLTER battery locomotive with a friction drive is used to transport people, materials, and equipment

drives (a motor with an inverter), a gear and friction drive wheels. The drive is transmitted by frictional coupling of the drive wheels with the rail. The drive wheels are pressed by a hydraulic cylinder, which presses the rocker arm towards the axis of the track through a lever. The gear is connected to the electric drive and the friction drive wheel is fixed in the rocker arm.

The braking system is used as a parking and emergency brake. Brakes are released after applying pressure to the brake release actuator, which moves the brake shoes away from the rail. The auxiliary unit includes an electric drive (inverter motor), which drives the hydraulic pump supplying the locomotive hydraulic controls.

The operation of the locomotive is controlled by the BWKS control box (in the manoeuvring version) or the control station in the operator's cabin. Optionally, the battery locomotive can be additionally equipped with a wireless control and radio communication system as well as mobile lighting for passenger stations and material stations.

The VOLTER battery unit is an explosion-proof device in a flame-proof enclosure. A VOLTER lithium battery is used to power the locomotive drives. The battery unit includes systems intended for monitoring, protection, supervision and control of individual locomotive devices. The battery compartment is equipped with lithium cells grouped in 20 boxes. Each box contains eight cells, which are monitored in terms of voltage and temperature by individual control modules.

The control modules communicate with the supervisory part located in the apparatus box and are also responsible for the cell charging process and for sending operating parameters to the control system. The advantage of the VOLTER battery is the charger integrated with it (installed in a special compartment of the battery enclosure), to charge the cells directly from the mine power grid. The mine grid is connected through a quick connector installed in the flameproof enclosure which significantly speeds up the connection/disconnection process. The charging time is up to four hours. The drive system of the VOLTER locomotive enables operation with energy recuperation, ie energy recovery back to the battery when travelling on a decline or when braking.

The use of battery-powered machines brings the following benefits to the working environment – elimination of exhaust gases, which results in a smaller amount of air required to dilute them; plus less noise and vibration improves the work comfort of the locomotive operators and the transported personnel. Operation of the locomotives does not interfere with the operation of fire safety systems (CO sensors) plus there is a big reduction of heat emission in comparison with diesel locomotives which has a significant impact on the improvement of climatic conditions in the excavations.

Summarising, the use of suspended VOLTER battery-powered locomotives brings the following technical and economic effects as well as benefits to the working environment in comparison with diesel locomotives: no exhaust emissions, low heat emission, quieter operation of the drive compared to a diesel drive, their operation does not interfere with the operation of fire safety systems (CO sensors), expensive logistics and diesel fuelling infrastructure are not required in the mine, plus they have lower operating costs. They also involve a shorter time for necessary maintenance, and has the possibility of charging the battery in excavations where electrical devices can operate in an explosion-proof enclosure, plus there is the possibility of charging directly from the mine power grid with a three-phase voltage of 500 V or 1,000 V.

Finally, VOLTER offers energy recovery when driving on a decline and when braking, monitoring of operating parameters and protections, remote control and data transmission, and optional radio control. Becker argues that battery-powered suspended locomotives, due to their advantages, are set to gradually replace diesel locomotives in the coming years.

PAUS introduces new MultiToolCarrier

German manufacturer **Hermann Paus Maschinenfabrik GmbH** told ***IM*** that it

Getman's ProMix ups the ante again in shotcreting operations

Getman concrete transport vehicles it says are purpose-built to maintain maximum reliability and uptime in harsh underground environments, delivering concrete where it is needed when it is needed. Purpose-built concrete transport vehicles are critical to ground support functions and construction works, and contribute to development and production advances by supporting shotcrete applications. Getman's new ProMix 6 features a horizontal drum mixer with 4.6 m3 (6 yd3) concrete transport capacity, and drum tilt mechanism to enhance concrete discharge on inclines and declines.

Getman Remixers include variable-speed hydraulically driven drums with bidirectional drum rotation, separate rotation speed and rotation on/off controls for optimal discharge control. ProMix concrete transport vehicles maximise worker comfort and safety by providing multi-directional seating for the operator, enabling forward-facing for forward tramming, and side-facing for reverse tramming. An optional dual side-view camera system enhances safety for both mine personnel and equipment, while additional work area lighting illuminates the rear working area for optimal safety.

IM spoke to Getman's Rick Kraft - Branch Manager; and Brian Ladouceur – Product Line Engineer, Concrete Spraying and Transport, for more info on ProMix

Q Do you have a customer that will test the pilot ProMix unit and are they an existing ProShot user?

RK The first ProMix is a production pilot build rather than a prototype. It represents an improvement over our existing Remixers, but is not a completely new design as the ProShot was. That said, we are shipping the first machine to a customer in the US, so we can fully support its launch as needed. We have quoted the ProMIx to several customers in Nevada who are current ProShot users. Getman has a branch office in Elko so support is local.

Q Would the aim or the norm be to offer both the ProMix and ProShot together as one solution for the customer?

BL The ProMix was developed to complement the ProShot, and the plan is to offer these together as a package solution for our customer's shotcrete application needs. The controls, technology, and serviceability are all similar to what is found on the ProShot, and the manoeuverability was improved to ensure that the ProMix can go wherever it needs to. However, the ProMix can also fully support many of the other existing underground concrete sprayers on the market today.

Getman's new ProMix 6 features a horizontal drum mixer with 4.6 m³ concrete transport capacity

Q Will a big part of the market entry be replacement of legacy Getman machines for these tasks?

RK Getman has a reputation for building highly durable machines for the underground environment. Our machines typically see well over 10 years of service with some machines having been underground for up to 40 years. The ProMix continues this same robust design philosophy, however, represents a step forward in technology. The new controls, attention to serviceability, and improved safety through enhanced visibility make the ProMix a strong investment for customers debating whether to purchase new versus rebuild. The ProMix is designed to compete not only with Getman legacy mixers but also with other suppliers. The new frame allows a lower profile using the same volume remixer drum. The ProMix will fit under any existing slick line or batch plant loading profile.

Q Do both units share a lot of parts commonality and is that a plus point when it comes to maintenance?

BL While the ProMix has many new features, it still shares a lot of commonalities with previous generations of Getman machines. Similar engine options between the ProMix and Proshot result in many commonly shared service items, and it shares the same electrical system design concept which was developed for the ProShot, including an intuitive 10 in touchscreen display in the cab. It's a good balance of combining proven, reliable components, common to Getman, and controls technology customers can expect from future Getman machines. The self-diagnostic capabilities of the ProShot have been integrated into the ProMix. Customers love this feature. It is a welcome improvement.

is launching a new machine mid-year for more flexibility in underground mines. The TSL 853 for small gallery sizes is already well established on the market. Now PAUS is set to launch a new series with new architecture, better working height, more operator comfort and lots of new technical features.

PAUS stated: "Due to the increase of requirements in underground mining and the changes in mine design, the vehicle and operation parameters have changed to more working coverage and more flexibility. The new MultiToolCarrier covers an area of 65 m^3. The telescopic arm can be extended to a working height of 9.2 m and swivels 45° to each side. The payload of the machine is up to 3.7 t, depending on the configuration."

It says the new machine can be used for a wide range of jobs. Thanks to the PAUS quick interchangeable plate on the telescopic boom and the ISO 3-point rear power lift, the machine can be equipped with a wide range of front and rear attachments. The quick-change system allows all attachments to be changed easily. "Typical applications include the man basket, but also shovel, pallet fork, loading hook, tyre changer and many other options. With an ANFO vessel and air supply attached to the rear of the machine, the equipment becomes an explosives charger; then the drill holes can be filled from the basket. The machine can be used for a wide range of applications, including material handling, mine maintenance, infrastructure improvement and production."

A unique feature is the self propel function from the man basket, which allows one-man operation. All functions, including driving, can be controlled and monitored from the platform. This gives the operator more flexibility, but also significantly more safety when working at height, as the controls can be taken over independently. There is no need for a second person in the cabin; two people in the basket can work on their own. Safety is further enhanced by safety standards such as inclination monitoring, safety-limited speeds and redundant sensors.

The basic concept of the machine is based on the proven P-platform. This is also the basis for the PScale 10-T, which has been successfully established on the market since 2020. Proven synergies such as the control system, motor and

The new MultiToolCarrier machine from PAUS can be used for a wide range of jobs

driveline as well as the radio remote control are available. Other options include Stage V engines and additional front supports.

The operator is located at the centre of the machine. The new control system offers a good overview and a high comfort for the operator. The diagnostic display shows errors on the relevant assemblies so that they can be easily corrected. The joystick function controls the machine centrally and is easy to use. A new enclosed, decoupled and isolated cabin gives significant noise and vibration reduction. As an option, the cab can be 20° hydraulically tilted and this improves operator ergonomics as well as increasing productivity.

The machine is exposed to extreme operating conditions that require special corrosion protection for the components. Easy maintenance of the various components and service from ground is given. PAUS offers a swivel-mounted cooler as a standard on the new machine. This makes the access to maintenance points much easier and quicker.

GHH's utility partnerships continue to bear fruit

Global underground equipment major **GHH**'s utility vehicle partner, UVB, based in Botswana, has undertaken an expansion program over the last 12 months to cater for the increased demand in the market. There is a new 1,800 m² factory nearing completion which is targeting at increasing factory floor space by 75%. This facility also includes a new plasma cutting facility for improved quality and throughput productivity improvements.

Regarding new developments UVB told ***IM*** that it has been extremely busy developing new products and optimising existing ones to keep up with customers' demands, predominantly across low profile markets in southern Africa. One of these is a large contract in Zimbabwe requiring the design and development of low profile shotcreting and shotcrete support vehicles (remixers). UVB has developed these over the last year and they are due to hit the market in the first quarter of 2024.

UVB have also developed a low profile tracked vehicle for use in high gradient (20 degree) development areas. The first one is a bulk emulsion tank but this design is modular and can be adapted to fit any requirement based on customers specific needs. And currently in development is a fleet of dedicated MV U60D range of vehicles, not cassettes like the established UV40 D range. These are individual and dedicated units for each utility type. With the constant growing needs for varied utility vehicles in the mining industry UVB says it has been extremely proactive in getting new products to market as they are required.

Similarly, the larger utility vehicle partner of GHH is **Titan Makina Ltd** has also been extremely active in the field of design and development. And it is seeing huge growth in the export of its Turkish-manufactured utility vehicles, with the support of GHH sales teams around the world.

The relatively newly released MUV5 light duty utility vehicle now has new variants, the VK and

Timberland's Minejack M30 MULE

Timberland Equipment has developed the new Minejack® M30 MULE, where MULE stands for Multi-purpose, Underground, Lifting and Loading, Emission-friendly (diesel with Stage V engine or battery electric versions available). Aaron VanMaanen, General Sales Manager at Timberland Equipment told ***IM***: "This is a unique machine being small, robust and versatile. It is meant to ensure that scoops are doing their job and not moving around other things or even people in an unsafe manner. That's why we designed this to have a quick connect front end with a man basket attachment, ANFO skid basket, fork lifts or anything that needs moving around." The articulating head on it allows it to turn tight corners even with an attachment on. Another unique feature is its ability to be radio remote controlled and put into a 'creep mode.' The lift arms are equipped with a hydraulic quick coupler system for connecting the multiple attachment types.

the MP. Both are specialised variants of Titan's Multi-Purpose Utility Vehicle and both variants now come with hydraulic stabiliser legs for operational safety.

The MUV-VK is a crane truck variant of the Multi-Purpose Utility Vehicle and comes equipped with a flatbed on the back and a crane with 1.84 tm lifting capacity. This vehicle has been sold as a smaller, more agile vehicle for lighter applications than the articulated crane truck, the BVK10.

The MUV-MP is a scissor platform of the same modular base. This Multi-Purpose Utility Vehicle comes equipped with a basket platform. The platform with a lifting capacity of 250 kg and a reach of 3,280 mm, and assists in most overhead installation operations and similarly to the MUV-VK variant, there is also a smaller, more agile and cost-effective option for lighter applications in the form of the BMP2X3, the BMP2X3, designed for overhead operations that require a smaller capacity. Both models can also be equipped with various optional equipment, such as a small-capacity compressor for power-tools and a welding machine for installation operations and is essentially customised to suit customers specific needs.

Finally, GHH told ***IM*** that its utility partner has also just completed the production and delivery of its first Articulated Cable Stringer, the BCS. This special purpose machine has been designed and manufactured by the request of a mining company. Critically required in mines with heightened amounts of water accumulation, the cable stringer was designed as an answer to the overhead cable installation challenge and offered an effective solution. With special attachments designed specifically for carrying cable reels and guiding cables into installation positions, this machine has the potential to streamline cable stringing operations in mines across the globe.

J.H. Fletcher's solution based approach continues

J.H. Fletcher has a long and proud history, which began in 1937, supplying rubber tyred tractors and timbering machines to the underground US coal market. ***IM*** spoke in-depth to Sean Jackson, its Business Development Manager: "Since then we have designed and developed many safety features that have now been adopted as standards today. This includes technologies like the Automated Temporary Roof Support (ATRS) system on its twin boom bolters plus its walkthrough design machines to protect machine operators from rib hazards and get them away from potential crush zones. Fletcher's vacuum dry dust drilling system was developed and patented in the early 1950s and is still in operation today." He added: "We pride ourselves on having spent the last 85 years providing solution-based equipment into the underground mining industry – both coal and industrial minerals as well as hard rock. We offer machines that are tailor made to the customers' applications. If they want a highly automated machine, we can do that – but if they want something with high production flexibility, we can offer a more manual design of machine."

In terms of products and markets it serves, it has a large base of coal customers both in the US and internationally. This primarily involves its production roof bolters of which it is the largest manufacturer in the world. It has produced about 5,500 of these of which over 3,500 are still in operation today. These production bolters can be split into three categories – low seam, mid seam and high seam. For low seam applications, it has the rubber tyred Low Roof Ranger II or Low RRII which can operate in 900 cm to 1.5 m. The RRII, DDR and CDDR are mid seam bolters for 1.5-2.5 m and are offered in rubber tyred or crawler versions. For high seams there are the HDDR and CHDDR machines which will cover 2.5-6 m plus are also available as rubber tyred or crawler machines. "All of these machines are capable of installing a very wide range of roof anchors and can be easily configured to install the anchors of the customers' choice."

Moving over to industrial minerals, mainly drill and blast with excavation type operations, which includes the large open gallery limestone operations in the US, Fletcher supplies its 3100 series single boom bolters which are suitable for drill and blast production rates while also serving remedial bolting applications such as installing cable anchors and mesh. It offers a 12 m high reach and very good visibility. "That machine we would refer to as a man up machine, so the operator is in a basket on the end of the boom and is placed adjacent to the drill, which gives them the best flexibility and operability for installing anchors safely and productively." It also offers a 3 t powder loader which is also designed to work in large cavern-like 9m high x 15m wide, room and pillar operations in the US but also Mexico where the mines have smaller excavations. This machine is also supplied into low-profile hard rock applications as low as 1.6 m.

Then there is the 3000 series range of single boom remote bolters – referred to as remote as in this case the operator is inside an air conditioned cabin. These machines are supplied with linear or rotary carousels which can hold up to 12 bolts. It also uses a dual indexing mast which allows for single pass drilling – it has a fixed length feed which permits computerisation of the drilling and roof mapping; this means it is capable of automatic drill and bolting cycles. If the customer requires it, Fletcher can offer resin insertion on these machines as well which is usually pneumatic.

Moving on to scalers, Fletcher offers its 3200 range of articulated scalers, which offer a 10 m wide coverage at a 5.5 m height. These have a maximum reach of 8.5 m and can be supplied with picks, hydraulic breakers or rotary cutter heads right up to a 160 kW capacity. The other range of scalers is the 3300 series which are crawler mounted scalers – plus their chassis spins similar to an industrial excavator. These are for operating in a 2 to 8 m height range.

On the drilling side, J.H. Fletcher also offers a large range of single and double boom face jumbo drills, though these would not normally be classed as utility machines.

Finally moving to hard rock, which Fletcher defines as anything from 200-220 MPa plus, it

J.H. Fletcher has a unique range of utility machines, including for industrial minerals operations with large room and pillar caverns

offers a narrow vein 3100 range of bolters which are man up machines and usually work in 2 m wide headings and a heading height of 4.5 m. Because of the hard strata being drilled, they are supplied with the HV-32 percussive drifter for wet drilling application.

And aside from its Fletcher branded solutions, in June 2022, it completed the acquisition of Cannon Mining – its portfolio includes drill jumbos, scalers, and roof bolters which have further broadened Fletcher's existing product lines. Additionally, the articulated frame utility vehicle product line is all new to Fletcher and includes scissor trucks, crane trucks, man baskets, and fuel/lube packages. Jackson: "Aside from products, Cannon is very strong in Mexico – so that is useful for us as well plus we can bring Cannon solutions into the markets where we are present, if there is a customer need. We have also chosen to keep the Cannon brand as it has good market loyalty and recognition."

Given this wide range of options, what is J.H. Fletcher's broader market focus and market strategy? Jackson commented: "We recognise that we have a very strong footprint in underground coal which includes a market leadership position in US coal, but we also recognise that the world demand for industrial minerals and precious metals is increasing, so we are actively diversifying globally. In terms of regional markets, our goal is to partner with distributors that are country-based and can offer our customers both technical and service support as well as understanding their needs."

He added that there have been some significant changes to Fletcher's global distribution model recently. Overall, the new international non-exclusive distribution model offers its customers maximum procurement flexibility and access to carefully selected authorised service providers, tailored to suit their territory-specific needs.

On personnel carriers and other utility vehicles that do not form part of its own portfolio, Fletcher has a new distributor agreement with UVB in Botswana to supply its range of machines into the US market. "They have a very broad offering range including 4, 6 and 10 t utility machines. They also have a range of dedicated underground personnel vehicles to replace converted Land Cruiser type vehicles underground. We already have a UVB Mine Scout unit in the US which we have been showcasing for our US customers and there has been a lot of market interest in it."

Finally on powertrains, Fletcher supplies both diesel and diesel electric machines, again depending on customer requirements. Its offering also includes both flameproof and non-flameproof options. It has also been developing battery electric solutions and in 2023 highlighted its new N3112-B/E Battery Electric Bolter designed for bolting in low to medium height conditions from 1.7 m to 3.66 m. "We are getting a lot of customer interest in BEV technology – but in the markets we serve there hasn't been a lot of commercial demand yet though we know it might come. I think for battery electric the product has to be geared to the application very specifically. Changes in operating parameters like conditions, duty cycles or shift patterns make reconfiguration both difficult and costly on BEVs."

Similarly on autonomy, including remote control, Fletcher is actively working with its technology-driven customers on these options though of course automation on a machine as complex as a bolter comes at an expense. "Fletcher prides itself in offering multiple levels of automation packages for its bolters and drill rigs. The systems are designed and tailored for site specific challenges to provide customers with maximum benefit. Automation in simplicity is the key. Fletcher automation systems are designed to be maintainable and user friendly, while installed on machines that are proven to be amongst the most reliable and robust in the world. This methodology ensures we unlock the full potential of the machine, delivering high performance and quality output, efficiently and consistently." IM

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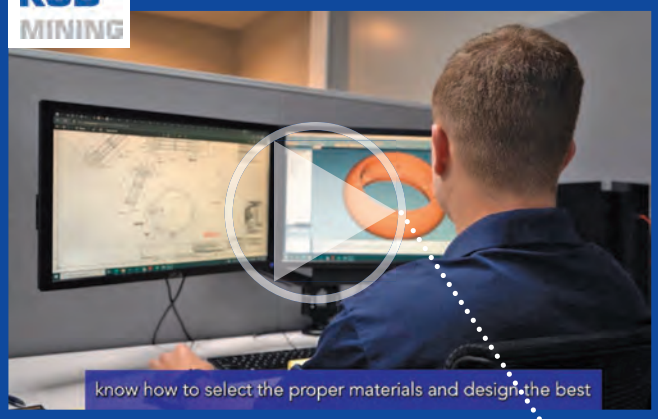

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Sensing an opportunity

Sensor-based analysis and sorting solutions are becoming even more powerful thanks to the incorporation of artificial intelligence (AI), data science and new sensor technology, Dan Gleeson reports

Having already successfully made an impact with its Fast Conveyor Analyzer (FCA) after the crusher in open-pit mining operations, IMA Engineering is looking for other entry points across mining where a conveyor-based sensor can add value

Without heterogeneity there is no pre-concentration or ore sorting business case.

This fact should remain front and centre for any mining company or consultant evaluating potential technologies to carry our pre-concentration or ore sorting at mine sites, realising that value generation is not a foregone conclusion.

All solutions on the market prey on such heterogeneity, with specific sensors suited to certain metals and materials. Data-backed analysis leveraging decades of metallurgical knowledge is changing things, however, allowing the detection of metals and minerals via proxies – further opening the field.

IM reviews some of the most widely considered business cases for pre-concentration and ore sorting in its annual review.

MineSense on untapped potential

MineSense has been making progress on several sensing, analysis and sorting fronts over the last 12 months, yet for Jeff More, President and CEO, the core power of its offering remains in the pit with its XRF-based ShovelSense® units.

ShovelSense uses X-ray Fluorescence (XRF) based sensing technology that is mounted directly to digging equipment such as wheel loaders and shovels to, MineSense says, accurately characterise and grade with each bucket, and differentiate between low-, medium- and high-grade mineralised material.

"What started as a way of making diversion decisions in the pit based on grade with ShovelSense has evolved into an offering that provides new datasets focused on downstream operations, particularly in the flotation circuit," More told ***IM***. "ShovelSense remains our killer product – and it continues to increase metal production through in-pit sorting – but we are moving progressively towards a more holistic offering powered by ShovelSense."

Called Mine to Mill Powered by ShovelSense, this offering assists geologists in the pit with grade-based information, as well as provides the likes of porphyry or skarn mineralisation categorisation for stockpiles of material metallurgists can act on. It is doing this through a combination of ShovelSense and the conveyor-based BeltSense®, the databank and machine-learning algorithms MineSense has built up with almost 25 installations across the globe, and the MineSense Data Portal – which enables access to real-time data generated by these units at critical points in the ore processing value chain.

"The datasets we now have, the algorithms we are creating and the well-established proxies or associations that the mining industry relies on are allowing us to go beyond what we initially thought was possible," More said.

For example, the company has been working on an entry into the spectral sorting space over the last 18-24 months, with plans to deploy a hyper-spectral imaging (HSI) unit across both BeltSense and ShovelSense for the generation of 'non-grade' characteristic data. This was predicated on offering up information that could be used to add value in the process plant.

More explained: "Grindability is one of the non-grade characteristic areas we were looking at HSI for in terms of potential correlations, but we're now at the point with our XRF-based systems where we have some interesting data on grindability with our current system that could be used to predict this."

The company's R&D teams continue to expand its spectral advances at the same time as the Mine to Mill Powered by ShovelSense population is growing.

The offering was initially demonstrated at MineSense's long-term customer site, Copper Mountain, in British Columbia, which involved multiple ShovelSense installations on excavators (in-pit), wheel loaders (stockpile) and conveyors. The second site to take on this full offering has been confirmed as Collahuasi, in northern Chile, one of the largest copper mines in the world.

The site has been using a ShovelSense unit in the pit for over a year now and is about to add a second for a stockpile application. In addition, it has plans to install BeltSense across its flowsheet at four locations in the plant.

Still in Chile, MineSense has recently added its first unit at a Codelco mine, installing a ShovelSense unit at the Ministro Hales operation. Plus, it has added Capstone Copper Corp's Mantos Blancos mine (also Chile) to its expanding list of ShovelSense references.

These wins have more than justified the company's investment in a recently-opened Santiago facility – which has offices, a manufacturing & service factory and data centre. "South America will represent our biggest region by the end of the year, taking over North America," More said.

MineSense sees the potential to open other dedicated hubs in strategic locations in the future, with More reflecting on recent ShovelSense inroads in Europe and Africa.

These aims are being aided by the company's exploits underground, which have also accelerated since ***IM*** last touched base with More.

Around 12 months ago, the company had just signed a contract with PT-FI's huge Grasberg copper-gold operation in Indonesia. This one-

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year product development agreement has already seen PT-FI roll out what More refers to as "ShovelSense Underground 3.0" at the block cave mine in batch operations, with the next step seeing the mining company use the unit in continuous operations.

At the same time, MineSense has been progressing the product development for this XRF-based solution in British Columbia, at New Gold's New Afton copper-gold mine – also a block cave operation.

Refinements to the sensor 'head' and shutter system – used to deal with the wet conditions experienced underground – have now been installed on units fitted on Caterpillar loaders running at both operations, with plans to move to commercial operation at Grasberg and New Afton shortly.

"Block cave mining is a great application for the ShovelSense Underground system thanks to the rock heterogeneity and flexibility associated with waste and ore stockpiles, but we see this system as having potential across the entire underground space," More said.

IMA conveying plant-scale ore sorting potential

Having already successfully made an impact with its Fast Conveyor Analyzer (FCA) after the crusher in open-pit mining operations, **IMA Engineering** is looking for other entry points across mining where a conveyor-based sensor can add value.

The XRF based FCA system benefits from sensing intervals as small as 10 seconds, allowing greater accuracy in low-grade bulk sorting or sensing applications, or potentially higher throughput analysis in less grade-constrained ones.

The company's FCAs have been used across the Americas, Africa and Europe, successfully analysing orebodies containing iron ore, copper, nickel and other metals. They are also being used in heap leach operations where the ability to measure not only grade, but also carbonate-related metrics could be used for optimising reagent use in the agglomeration process.

Ilpo Auranen, Chairman of IMA, believes there

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is potential for the company to combine this type of analysis with sensor-based particle size distribution (PSD) readings – via a tie-up with a partner – to optimise throughput in the mill. When adding ore tracking, via RFID-based tags, IMA can help reconcile not only grade-based data at various parts of the process flowsheet, but also the impact of material hardness on the various processing stages.

"Because we detect the 'markers' or 'signatures' on the conveyor belt, we know the real grades, the material size and where the material has come from," he told ***IM***. "This teaches operations about the waste rock dilution and size considerations that may be impacting recoveries, energy consumption and more in the mill."

Having already successfully brought its AutoSampler solution for blasthole sampling from the open pit to underground mining environment, the company is looking to make a similar transition with its FCA and other sensor solutions.

IMA has been working on a project to mount its sensors at strategic locations on underground haulage routes to provide XRF-based LHD bucket payload scanning. It now also sees an opening for providing grade-based information and more in underground conveying and hoisting applications.

Auranen explained: "As mines go deeper and move away from ramp-based infrastructure to shafts, they use hoists to lift ore and waste to surface or to other parts of the underground mine. We can leverage the underground infrastructure already in place – the skip-load conveyors that transport material and the mechanisms for dispatching this material – and provide readings that allow the operators to decide if that 10-20 t load should go to a waste stockpile or to the processing plant."

These skips are already fitted with weightometers and scales, so the grade-based information can be reconciled against a certain tonnage of material and tracked throughout the operation.

"In the mining environment there are several steps where the material moves by conveyor and that is an obvious target area for us with the FCA solution, providing an optimisation opportunity," Auranen said. "The skip loading area is just one of these."

In the ideal setup, IMA would have several FCAs or other sensor-based solutions across the flowsheet to provide as much information as possible to be used for total mine-to-mill process optimisation and reconciliation purposes.

These would be complemented by automated sampling and analysis units, such as the multiplexer-based IMACON 100 for slurry analysis, to provide the quality assurance/quality control operations require for improved decision making.

The OG7 system successfully underwent testing in Australia and is now in the final stages of commissioning at a large copper mine in Africa

NextOre widening the MR proposition

NextOre also has a strategy for expanding its mining presence underground with a variation of its open geometry, magnetic resonance (MR) sensor.

MR technology comes with no material preparation requirement and provides grade estimates in seconds, NextOre claims. This helps provide "complete transparency" for tracking downstream processing and allowing operations to selectively reject waste material.

The OGX Sensor – which stands for open geometry and the stated diameter of the sensor – first came to light in Australia as a 3-m-wide unit made by CSIRO to be used in a material feeder setup in 2022. Testing of this unit was observed by several major mining companies and laid the groundwork for a bigger installation – a 7-m-wide ruggedised antenna that can be positioned over an open-pit haul truck and manoeuvred using a crane and guidance systems. This system successfully underwent testing in Australia and is now in the final stages of commissioning at a large copper mine in Africa.

The advantage of both scenarios, just as with a conveyor, is the ability to make accurate, whole-of-sample grade measurements at high speeds.

It is the 3-m OG sensor that could end up being used underground, as Chris Beal, CEO of NextOre, explains: "We are looking at modifying the OG3 sensor so it can be used to scan material in the bed of a typical underground mining truck. This is a similar process to what we have in place for the OG7 at the surface mine."

This project has been driven by the needs of a client in Australia with an open stope mine that has observed high heterogeneity within the orebody it is mining.

"This company sees the benefit of being able to separate material underground and in small open stope and fill conditions where you may be able to avoid trucking material all the way from the bottom of the mine to the surface and back again," Beal told ***IM***. "With the help of the sensor, they could effectively dump material that has been analysed and categorised as waste back into the open stopes."

NextOre currently has around 40 tonnes of material at its New South Wales workshop being scanned by this sensor in a static setup to gain a baseline.

In the meantime, the company has plenty of work ahead of it with its Conveyor System Ore Analyser and Mobile Bulk Ore Sorting Plant.

The former has been installed at several mines across the globe, with the highest capacity installation in Chile as part of a 6,500 t/h conveyor application being used for data reconciliation. It has also successfully proven the ore sorting business case on a 2,800 t/h installation at First Quantum Minerals' Kansanshi copper mine in Zambia.

The latter Mobile Bulk Ore Sorting Plant – able to sort 100-400 t/h of material on a 900-mm-width conveyor belt while running at 0.3-1 m/sec – has been used at Aeris Resources' Tritton copper operation in New South Wales, where the unit took material on the first surface stockpile from an underground mine.

Beal said the same plant is currently at NextOre's factory being refurbished with a new sensor unit, but there are already three sites looking to use it to compress the timeline normally associated with making a business case for a commercial ore sorting installation.

"We should be ready to push the plant out of our facility for deployment around April," he said in early-February. "We are currently evaluating three options – in Australia, Chile and Brazil – where the unit could go. It will all depend on how quickly these sites can move in terms of bringing it to the mine."

NextOre is making plans with its partner manufacturers to build two more units to fill demand for these Mobile Bulk Ore Sorting Plants, with Beal hopeful of servicing all three of these mines in due course.

Demand for NextOre's MR-based solutions across many different applications continue to ramp up on the back of the technology's ability to provide fast and reliable bulk measurements that could lead to increased metal production from smaller process plants, it says. This all comes with lower water, electricity and chemical consumption for the same amount of production.

It was these qualities that led **Gebr. Pfeiffer**, a Germany-based comminution company, to make an investment in NextOre and partner on its mission to deliver sustainable breakthroughs in processing technologies.

Under a recently signed strategic cooperation agreement, NextOre and Gebr. Pfeiffer are collaborating to explore opportunities to combine their respective technologies to drive a step-change in efficient, environmentally-friendly minerals processing using:

- NextOre's MR sensors and real-time bulk ore sorting to allow companies to, it says, achieve more metal production from smaller plants with lower environmental impact; and
- Pfeiffer's vertical roller mill technology for dry grinding, which, it says, provides a substantial benefit in energy saving, delivers a uniform size reduction with a narrow PSD, provides a high reduction size ratio of up to 1,000 and is highly flexible.

Already the two companies have been in discussions with clients about combining the technologies in both the copper and iron ore space, realising the combination could provide optimum and fast adjustment of the grinding process to the incoming material, reduced concentrator size with retained metal output, and no use of resources for processing of waste materials.

Beal explained: "Bulk ore sorting is about giving you more metal from a smaller processing plant. Dry grinding is about being able to reduce electricity and water consumption as well as giving you higher recoveries at coarse grinds. Oversimplifying this combination, you can see many projects where the two would represent a game changer – remote projects in arid environments, limited access to water and electricity, as well those facing social and environmental pressures."

And already Gebr. Pfeiffer is working on designs for both 4,000 t/h and 10,000 t/h diverter gates as part of a joint project in Latin America that could see the companies and engineering firm Worley collaborate on a bulk ore sorting and sensing project.

Mathias Dülfer, Gebr. Pfeiffer CEO, told ***IM***: "This potential project shows how quickly the collaboration between the two companies has started.

"When looking at the combination of our dry grinding solutions with NextOre's bulk sensing and sorting solutions, it makes sense to start with copper and iron ore. We are frequently performing tests at our laboratory focused on these two metals and NextOre's technology has also been shown to work effectively on both."

He concluded: "From our most recent discussions with mining clients, we are seeing projects being evaluated on not only economics but also the environmental impact their production will come with. The combination of these two technologies will provide the solutions to many of the challenges the industry is currently facing."

PFTNA in the elemental analysis mix

Malvern Panalytical and its pulsed fast thermal neutron activation technology (PFTNA) based solutions have been used by the mining industry for close to 15 years now – for measuring sulphur and calorific values in coal, sintering optimisation in iron ore, and nickel processing, among other applications.

They are now being leveraged across the commodity suite, with mining companies using the elemental analysis for grade-based readings on a bulk sorting scale.

PFTNA uses an electrical tube to provide a pulsed flow of neutrons that interacts with the nuclei of the atoms in the passing material. In response, the atoms emit gamma rays at characteristic energy levels. These gamma rays are measured with scintillation detectors and high-speed electronics to collect the spectrum of emitted gamma rays, with the spectra interpreted

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Rajendra Mishra, Product Manager for Malvern Panalytical's Cross-Belt Analyzers (CNA), said the "bulk analysis" benefits that come with this neutron-based technology – able to direct 14 million electron volts onto the conveyor belt – allow mining companies to get a true picture of the mineral composition of material on a conveyor belt.

"When compared with the traditional Californium-252 neutron source for prompt gamma neutron activation analysis (PGNAA) – which offers roughly 2.5 million electron volts – we are able to detect much smaller concentrations of minerals and metals," he told ***IM***.

Such characteristics fit the needs of many base metal operators suffering from grade depletion, hence the reason why Metso signed up to a non-exclusive collaboration agreement with Malvern Panalytical back in 2022 to provide high-speed, sensor-based bulk ore sorting solutions to the mining industry.

It is also the reason why many miners – major copper and nickel producers included – are already leveraging Malvern Panalytical's conveyor-based solutions, which it provides through its ties with SODERN, a subsidiary of the Ariane Group, the largest aerospace company in Europe and the second largest worldwide.

Neutron-based solutions continue to prove effective on the 'bulk analysis front', but there is an amount of reticence from new customers around the perceived safety issues that come with potential radiation exposure.

Uwe König, Head of Business Development for the Mining and Metals team at Malvern Panalytical, said these safety concerns have risen up the agenda following the heavily documented radioactive capsule loss that occurred in Western Australia in 2023.

"One advantage of PFTNA is we are using an electrically-operated neutron tube that has an on-off mechanism to ensure neutrons are not emitted when the unit is switched off," he said. "Most operations also have safety fences around installations to ensure personnel are not exposed to radiations by inadvertent entry."

In addition to these comprehensive safety precautions, Malvern Panalytical follows a stepwise approach to applying its solutions at mine sites. This sees it calibrate its sensors with the help of representative material samples from the client, testing the solution at laboratory and pilot scales and then carrying out a full-scale implementation verified through further lab-based testing.

The ability to move from ore analysis to ore sorting using PFTNA is one that requires more than just Malvern Panalytical and SODERN's input; it also requires a solutions provider able to 'actuate' the sort with a matching speed.

This comes back to the Metso agreement.

König said: "We came together with Metso as we worked with them on other solutions, and it was very much a case of 'one plus one equals three'. They had sorters, we had sensors and the combination was a great fit to approach customers on a joint basis."

The two companies have been carrying out testing on several projects in the mining space and are confident of this leading to commercial installations.

In the meantime, Malvern Panalytical can reflect on successful tests with a major mining company on an 'open format' PFTNA sensor mounted after the primary crusher to carry out elemental analysis of rocks up to 300-400 mm in size for oxide and sulphide differentiation; on proxy-based precious metal detection; and potential in tailings management, heap leaching and metal recycling applications.

König added: "We also see the digitalisation trend with sensor readings where customers want to measure all the ore on the belt and predict the energy needed to process this material later on, or the water required for processing."

This is likely to see PFTNA sensors working alongside other sensors backed by analysis from AI-based algorithms to solve the major challenges the industry faces.

On that front, Malvern Panalytical is well prepared, working on the potential to integrate a Near Infrared (NIR) sensor into this mix, having an awareness of what Metso is proposing across the wider flowsheet with the separate agreement the OEM has with TOMRA Mining on particle sorting, and making plans to adapt some lab-based software and maintenance platforms for its CNA customers in the field.

Scantech on the PGNAA value drivers

Henry Kurth, Chief Marketing Officer of **Scantech International**, has previously referred to bulk sensing as a 'digitalisation tool' that generates data to be used simultaneously for multiple applications.

Such a reference emerged while highlighting Scantech's GEOSCAN-M PGNAA-based sensing solutions, which have been used for decades by the mining sector – in coal, iron ore, phosphate and about a dozen other commodities. These systems measure the elemental composition continuously in real time, through the full conveyed cross section so the entire flow can be representatively measured. Unique advantages of the GEOSCAN-M are that it is proven on belts containing steel cords and chlorine (such as FRAS rated belts used underground) and measures ores such as potash containing high chlorine levels or those with rare earth elements, the company says.

All GEOSCAN-M installations are conveyor-based and are custom-configured to specific applications that determine the frequency and precision of the results, according to Kurth. "It tends to be more frequent and higher precision in bulk sorting, a little less frequent for normal measurement, and possibly longer for blending control," he said.

For any of these applications, the value of the data comes by providing a better understanding of ore and waste quality variability over short timeframes and tonnages compared with larger tonnages in shovels and trucks and very much larger tonnages in orebody block models and blast designs, Kurth explains.

"The high-resolution data from the short, conveyed parcels provides opportunities for improved selectivity and fine tuning of decisions to influence the grade received by the process

GEOSCAN GOLD specification analyser measuring each 30 seconds of conveyed flow for bulk ore diversion

plant or reporting to product stockpiles," he says.

In this context, Scantech's role is to provide measurement solutions to help solve customer problems. Here, data is not a solution in itself but an enabler, enriching knowledge about the material it measures. "It is the starting point of a potential solution, which usually involves other processes (diversion, feed proportioning, etc)," Kurth explains. "Once the quality of the material analysed is quantified then opportunities to understand, control and improve arise in the classic continuous improvement cycle."

Kurth provides an example involving pebble circuits, whereby mill oversize is recirculated, often via a pebble crusher, back into the mill feed. "Here, we question: why is hard to grind material recirculated if it is below economic cut-off grade quality? It can occupy up to 30% of a mill's capacity at some sites, meaning throughput is significantly reduced and costs per tonne of product are higher."

This is where Scantech's PGNAA analysers would provide the reading on the value of the pebbles, with those below cut-off grade able to be diverted through a mechanism after bulk analysis to a waste dump or even a particle sorter to recover what few particles of ore quality may be present, if any.

This is the type of customisation and collaboration that Scantech routinely offers clients.

"This includes configuration (different sizes), specification (a range of features, components, measurement times, minimum 24-month warranty), customised calibration by element to their composition ranges (performance guarantees) and combinations of sensors (elemental, moisture and PSD) to ensure we offer the optimal solution," Kurth said.

Scantech claims to be the only provider of representative direct gold measurement in primary crushed conveyed ore through its GEOSCAN GOLD analysers, and measures carbon directly in conveyed flows, so this is one commodity, specifically, where Kurth sees much interest.

Most of the GEOSCAN GOLD installations the company has installed to date are measuring the yellow metal – as opposed to diverting characterised material – yet Kurth sees gold ore

recovery from waste zones as representing a profitable application assuming conveyors are long enough for the required direct gold measurement times prior to reaching the diverter system.

AI unlocking new particle sorting potential

Particle sorting has already had mentions in this article from the bulk sorting community, hence its importance across the wider pre-concentration and ore sorting space.

One of the leaders in this field is **TOMRA Mining**, which recently invigorated its offering with the help of a sophisticated deep-learning platform called OBTAIN™.

TOMRA has been using machine learning in its X-ray Transmission (XRT) and NIR sorters for the last 10 years but OBTAIN is set to open a new era in sorting, the company says.

OBTAIN goes a step further, leveraging deep learning to bring single-particle precision to high throughput particle sorting, TOMRA says.

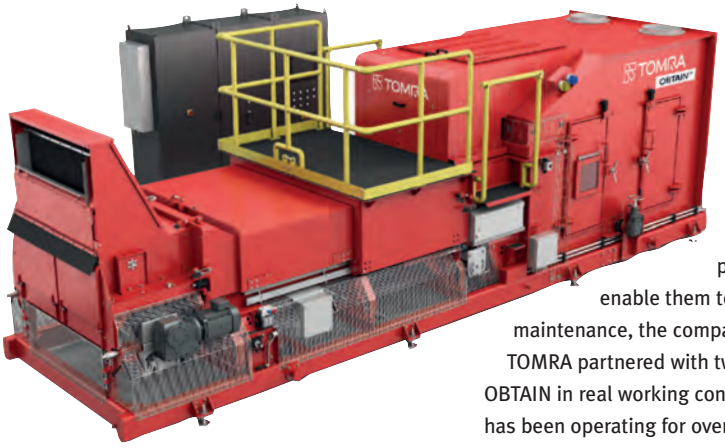
The software uses a neuronal network to identify the properties of each particle accurately and independently of the sorter's capacity, achieving new-found precision and reliability in detection and ejection. Based on its specific requirements, the mining operation has the flexibility to either enhance the throughput of the sorter while maintaining consistent sorting efficiency, or improve sorting precision – ie recovery – without compromising the existing throughput.

When asked about the maximum throughput of the COM XRT 2.0 – TOMRA's biggest particle sorting machine – when equipped with OBTAIN, Stefan Jürgensen, Software Team Leader, R&D at TOMRA Mining, said the volume depended on factors like PSD and commodity-specific requirements. "OBTAIN enhances both the throughput and the quality of the sorting process, but it does not have a fixed value for all cases," he told ***IM***. "OBTAIN ensures consistent sorting quality across different throughput levels."

Sorting of very low-grade material often depends on sufficient liberation of the ores. Further crushing of the material increases the belt occupancy and particle count considerably. The resulting reduced distances between particles negatively impact the sorting quality in conventional sensor-based sorting. As OBTAIN brings single-particle precision to high throughput sorting, it makes the processing of low-grade ores more cost-effective than ever before, according to Jürgensen

He added: "Traditional sensor-based sorting technologies can only maintain a certain quality level up to a limited throughput. Beyond this limit, quality declines due to constraints in physical separation, material presentation and data processing. OBTAIN enhances the detection and evaluation of each particle on the sorter, which enables higher feed rates without compromising product quality. This means that operators don't have to slow down the feed to use OBTAIN."

The addition of OBTAIN allowed a long-standing customer in a magnesite application to double the feed on the sorter without compromise the sorting quality. In fact, the sorting quality improved, demonstrating the efficiency and effectiveness of the OBTAIN system, Stefan Jürgensen says



OBTAIN works best on ore sorting units with the new high-resolution TS100C ejection module, which is fast and extremely precise, according to Jürgensen. The module also has the added benefit of significant energy savings because it uses much less compressed air to eject the particles than other ejection systems.

On top of throughput and recovery, OBTAIN can also add value to a mining operation with a wealth of extremely detailed and accurate data, such as precise online PSD of the feed, the company says.

This online PSD analysis offers near real-time monitoring of material streams by assessing each particle, according to Jürgensen. "It delivers continuous insights into mineral composition and crushing patterns, further enriched by sorting statistics on the detected materials," he said. "This immediate, accurate observation enables operators to respond swiftly to changes, improving productivity and cost-effectiveness. It is particularly valuable in high throughput mining and mineral processing quality control, where prompt decision making is essential."

When used in combination with TOMRA Insight, OBTAIN can provide the customer with detailed reporting on the performance of the sorter and its components to help them optimise the process, as well as enable them to plan for predictive maintenance, the company says.

TOMRA partnered with two customers to test OBTAIN in real working conditions. The software has been operating for over 18 months at the Wolfram Bergbau & Hütten tungsten mine in Mittersill, Austria, where it has delivered consistent and reliable performance. The vicinity of the mine to TOMRA's development team, based in Germany, made it a suitable testing ground for the first phase.

Jürgensen said Wolfram Bergbau & Hütten AG was operating its sorter at the maximum feed rate of its underground tungsten mine, with the primary objective of using OBTAIN being to improve the sorting precision. "With the installation of OBTAIN, they not only achieved this goal but also gained the ability to sort additional, finer material," he said.

The second phase of testing the company has carried out to date is with a long-standing customer in a magnesite application. Jürgensen said this customer was already using its sorter at maximum capacity, but the addition of OBTAIN allowed it to double the feed on the sorter. "Remarkably, this increase in throughput did not compromise the sorting quality," he said. "In fact, the sorting quality improved, demonstrating the efficiency and effectiveness of the OBTAIN system."

The OBTAIN software has been developed for TOMRA's XRT sorters. It is available on new

SpectraFlow Analytics has recently received an order from Vale for a Crossbelt Analyzer as part of the mining company's quality monitoring processes at its iron ore dispatch terminal of Ponta da Madeira, in Maranhão, Brazil.

This is the second order from Vale and the third order for a minerals Crossbelt Analyzer in South America.

The company said: "After the very successful installation of a SpectraFlow Crossbelt Analyzer for the same application in the Terminal Ilha Guaíba, in Rio de Janeiro, this is now the second installation of a SpectraFlow Analyzer within Vale to enhance the ship loading with real-time data."

SpectraFlow analysers are already installed in the cement, iron ore, gold, platinum, copper, potash, bauxite and recycling industries. They leverage NIR sensors, providing measurements of dry raw material composition at key points in mining, processing and refining value chains.

models, but there will also be an upgrade package available for existing machines.

STEINERT makes its case for chrome sorting

It is the combination of an XRT sensor with three other additional sensor options that is helping Companhia de Ferro Ligas da Bahia (Ferbasa) avoid unnecessary processing by separating a fraction of the high-grade material from the metallurgical process feed in advance, according to **STEINERT**.

Ferbasa is in Ipueira, a municipality in the state of Bahia in Brazil. It operates one of the largest chromite mines in the country and is considered a pioneer in the use of SBS technology, STEINERT says. The company processes chromite obtained from an underground mine, with the extracted material pre-concentrated using sorting technology that it employs.

With a processing capacity of 12 Mt/y, the company has been using sensor-based sorting for 10 years in a completely dry process that separates waste from high-grade chromite.

Eriberto Nascimento Leite, Mining Director at Ferbasa, says the ability to avoid unnecessary processing by separating a fraction of the high-grade material from the metallurgical process feed in advance using SBS removes the requirement for additional processing. In that way, particles considered uneconomic are eliminated from the process beforehand with only valuable material undergoing the follow-on concentration steps.

At Ferbasa, the use of SBS technology has enabled an increase in production, in addition to reducing costs in the subsequent processes, such as comminution and the use of inputs (reagents).

"Today, at Ferbasa, SBS technology helps us adopt ESG practices, reducing waste, maximising production efficiency and contributing to the conservation of natural resources," Nascimento says.

Nowadays, it is not only the mined ore that is processed, but also the stockpiles, which contain considerable amounts of chromium. The treatment of these stockpiles is only possible thanks to process automation and high-capacity levels, which reach up to 180 t/h.

Stockpile treatment has the potential to increase productivity in the mine, while, in terms of resource use, there is potential to reduce the consumption of water, energy and chemical reagents primarily because SBS is a dry separation process.

Ferbasa started operating its first sorter in 2014 and, by 2019, it had six units installed for the processing of run of mine and low-grade stockpiles.

The production benefits from flexibility of the sorting systems, which generate waste material, pre-enriched material and high-grade material. The processing capacities are up to 120 t/h for particles of 25-76 mm, reaching up to 180 t/h for particles from 51-127 mm. In terms of the sizes processed, the combination of sensors facilitates the separation of particles up to 127 mm – a feature that, STEINERT says, reinforces the robustness and efficiency of the equipment for the detection and ejection of extremely coarse particles. In total, recoveries reach values of up to 90%, with upgrades of up to 1.5-3 times the feed levels.

Currently, Ferbasa applies SBS technology to process 100% of its run of mine, using two units from STEINERT – the STEINERT XSS T and STEINERT KSS | XT L – in a two-step process.

In the first step, waste material is rejected, and, in the second, pre-enriched and high-grade materials are generated. The high grade-material meets the content specifications to be sent to the metallurgic plant, while the pre-enriched material is sent to another plant to follow other concentration procedures. Furthermore, the technology is applied in the processing of low-grade stockpiles, using two STEINERT KSS | XT L units – which combine the XRT sensor with another additional sensor for 3D shape information and surface characteristic (opacity and crystal) structure – in two steps to separate waste, pre-enriched material and high-grade material. As a result, the low-grade stockpiles are processed in an economically viable way and with high sustainability gains.

At Ferbasa, the use of STEINERT SBS technology has enabled an increase in production, in addition to reducing costs in the subsequent processes, such as comminution and the use of inputs (reagents)

Rados XRF+ breakthrough in lithium sorting

Rados says the successful installation and commissioning of the Rados XRF+ MODOS sorting plant module at Marula Mining's Blesberg lithium and tantalum project, in South Africa, has caught the attention of lithium miners, with the technology company having since been inundated with requests for test work and project proposals from the sector.

Jason Brewer, Marula Mining CEO, said in a recent announcement: "We are incredibly proud of the advancements made during the commissioning and optimisation of the Rados ore sorter at Blesberg. The successful commissioning and bulk testing and production not only signifies a major leap in our operational capabilities, but also positions Marula at the

Rados XRF+ MODOS plant at Blesberg

forefront of the industry, as we use AI (artificial intelligence) sorting algorithms in our processing technologies."

He added: "Achieving up to 89% recovery rates and the capability to process lithium ore with efficiency and precision is a testament to our team and their commitment to innovation, as well as our partners at Rados. These results also support our aim to deliver significant volumes of a saleable high-grade lithium spodumene product this year."

One of the highlighted features of the Rados XRF+ MODOS sorting plant module is its AI-driven algorithm to manage Blesberg's pegmatite ore. This AI system, operational both in the laboratory and on site, effectively adjusted to the mine's spodumene XRF+ spectrum patterns, securing high recovery rates and maintaining consistent product quality, the company says.

The Rados XRF+ MODOS sorting plant module's performance at Blesberg represents a milestone in the mechanical dry processing of lithium ore, achieving spodumene recoveries consistently exceeding 85%, it added.

Rados explained: "The sorter's ability to identify and sort a variety of spodumene, other valuable minerals and waste types, based on unique XRF+ characteristics, underscores its contribution to improving grade control and product quality."

The Rados MODOS plant was delivered within a three-month timeline and required just an additional three weeks for on-site commissioning and training at Blesberg. The plant module was supplied on a turnkey basis, underpinned by performance and cost warranties, with Rados saying the MODOS plant performance continued to comply with the contractual performance warranties.

Rados says its initial future focus for this particle sorting focused solution will be on lithium/tantalum, lead/zinc, silver, copper, cobalt and gold, where significant sorting value propositions have been demonstrated in test work.

On the bulk sorting side, Rados and MMD continue to build on their collaboration, with plans to soon present a new In-pit Bulk Ore Sorting Solution. This, Rados says, shall complement the existing online Bulk Ore Sorting Solution provided by Rados and MMD.

The online Rados and MMD Bulk Ore Sorting Solution integrates feeding, sizing, sorting and conveying equipment from MMD as well as the Rados Conveyor Belt Analyser (Rapbos CB) for real-time grade control. This ensures a tailored ore feed for consistent performance and reduced downstream process variations, Rados says.

This approach efficiently eliminates 10-30% of barren ore upfront, preserving high recovery rates and supplying higher-grade ore directly to the processing plant, according to Rados.

Bunting beefs up overband magnets

In magnetic separation, one of the key solutions used to separate material on a conveyor belt is an overband magnet.

The highest wear part on an overband magnet is the belt that transfers the separated metal away from the conveyor and into a collection area. To reduce such wear, **Bunting** developed a special lightweight armouring for the rubber belt.

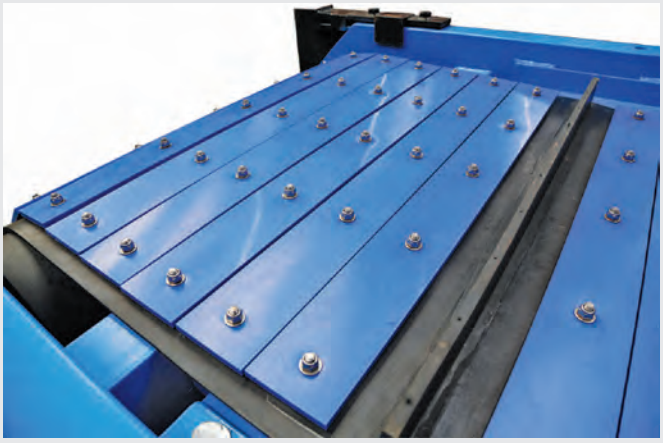
In operation, an overband magnet sits over a conveyor transporting materials such as aggregate, waste, shredded wood or mined ore. The magnetic field of the overband magnet, generated by either a permanent magnet or an electromagnetic block, attracts ferrous metal from the conveyed material up and onto the revolving self-cleaning belt. Rubber upstands on the belt catch the lifted metal, transporting it away from the conveyed material into a separate collection area.

The force of the ferrous metal striking against the self-cleaning rubber belt is significant due to the magnetic attractive energy of the permanent or electromagnetic block increasing as the metal moves closer to the face. This means the metal is accelerating into the belt. The moving belt becomes sandwiched between the lifted metal and the magnetic block momentarily, until the upstand catches and drags the item away and out of the magnetic field.

Applications in which self-cleaning belts experience high levels of wear include:

- When there are high amounts of ferrous metal present in the conveyed material;
- When the ferrous metal is large and heavy;
- When there are nails or thin and sharp ferrous metals; and
- When the magnetic block has additional magnetic force, as with the ElectroMax and ElectroMax-Plus models.

To combat excessive wear and extend the life of a self-cleaning belt, Bunting's engineers have designed a lightweight but heavy-duty armouring for the belt. There were other options, including special wear-resistant belt coatings and other types of rubber belt, however the armouring provided unrivalled protection, significantly lengthening belt life, according to Bunting.



To combat excessive wear and extend the life of a self-cleaning belt, Bunting's engineers have designed a lightweight but heavy-duty armouring for the belt

The armouring on the rubber belt is comprised of high-density polyethylene (HDPE) slats. Each slat is 100-mm wide and 10-mm thick, with a length to suit the model of overband magnet. The slats are fastened to the belt using special 304 stainless steel elevator bucket bolts and nyloc nuts.

"The introduction of this design of armoured belt has proven very popular," Adrian Coleman, Bunting's Technical Director, says. "Other types of belt armouring have proven unsuccessful, but the HDPE has worked exceptionally well."

The importance of process design in ore sorting

The success of a mineral processing project hinges on a meticulous and well-orchestrated process design, with **Stark Resources**, a specialised, privately held engineering group with a global mining footprint, looking to prove this out in the ore sorting space.

The team at Stark Resources excels in crafting comprehensive process designs tailored to the specific needs and challenges of each project

"The team at Stark Resources excels in crafting comprehensive process designs tailored to the specific needs and challenges of each project," Dian Heinrich Page, Group Head of Advisory for Stark Resources, says. "Its proficiency in conducting exhaustive metallurgical studies enables it to provide the advisory services essential for navigating the complexities of mineral processing with confidence and precision."

Central to Stark Resources' approach is the specialisation in developing flowsheets and implementing process designs for ore sorting – technology that can improve the efficiency and productivity of mineral processing operations and contribute towards reducing their environmental footprint.

By leveraging advanced technologies and strategic insights, Stark Resources says it empowers clients to optimise resource utilisation, enhance product quality and streamline production workflows.

A foundation of the validation of a process design is the construction of pilot plants – a crucial testing ground where theories are put into practise on a smaller scale, and operational parameters are fine-tuned before full-scale implementation. Stark Resources says it possesses the expertise and capabilities to construct and operate pilot plants, enabling clients to identify potential bottlenecks and refine operational strategies while generating early cash flow.

Notably, an upgrade ratio of 1.1-1.3 times results in a 10-30% increase in metal production without altering tonnage, thereby enhancing economic viability while meeting ESG objectives such as improved energy efficiency and reduced water consumption.

Rados added: "To make these solutions accessible, clients can trial the technology without significant upfront investment. This trial period involves the temporary installation of the Rados Rapbos CB on the client's operational belt for three months." During this time, extensive data is collected about the client's orebody and its unique characteristics.

By leveraging Rados' technology alongside MMD's machinery, clients can accurately assess the potential benefits and value of implementing such solutions within their operations, Rados says.

In addition, to offering clients a low capital entry into the Bulk Ore Sorting Solution, the data generated from Rapbos CBs can be used within a digitalisation context, providing information on the elemental content, the mass and the volume of the ore stream to potentially facilitate improvements and optimisation of downstream processes and material handling solutions.

Comex reflects on ore sorting century

Comex is looking to tackle what it sees as the main problem in pre-concentration – high content material in waste fractions caused by inaccurate sorting – with a new patented sorting system able to, it says, achieve high precision separation at low mineral grades.

Comex has delivered almost 100 sorting solutions for mining applications worldwide, many of them for demanding applications in copper, gold and rare earth element (REE) ores, where high sorting precision is critical for sustainable plant operation.

Its system employs high selectivity X-ray detectors operating together with other sensors, like RGB and Short-Wave-Infra-Red cameras, installed in the same sorting unit. This combination, it says, significantly increases the number of parameters describing processed materials, allowing accurate identification of ores representing metals like nickel, copper, gold, zinc, tungsten, REEs and others.

By providing detailed analysis of the internal particle structure by XRT sensors and the particle surface through additional optical cameras, it is also possible to detect waste rock and minerals containing no valuable material, it says.

"This is carried out via special correlation models, which compare data from different sensors," Comex explains. "Advanced digital filtration tools with smart data fusion are used to compare information available in different formats and resolutions."

This potentially huge data stream is difficult to analyse in an optimal way – where efficient data processing is carried out in short time intervals – so the company employs AI-based models with convolutional neural networks to achieve optimal decision making.

The most notable application of one of Comex's sorters was seen at a gold mine where 85% of the waste rock – in the form of large rock – was removed ahead of the processing plant without lowering metal production. "This made it possible to eliminate 85% of the fine flotation waste, obtain corresponding energy and cost savings, and increase the gold content from about 1 g/t to 5-6 g/t for further processing," it said. IM

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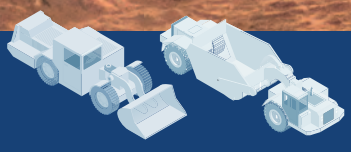

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