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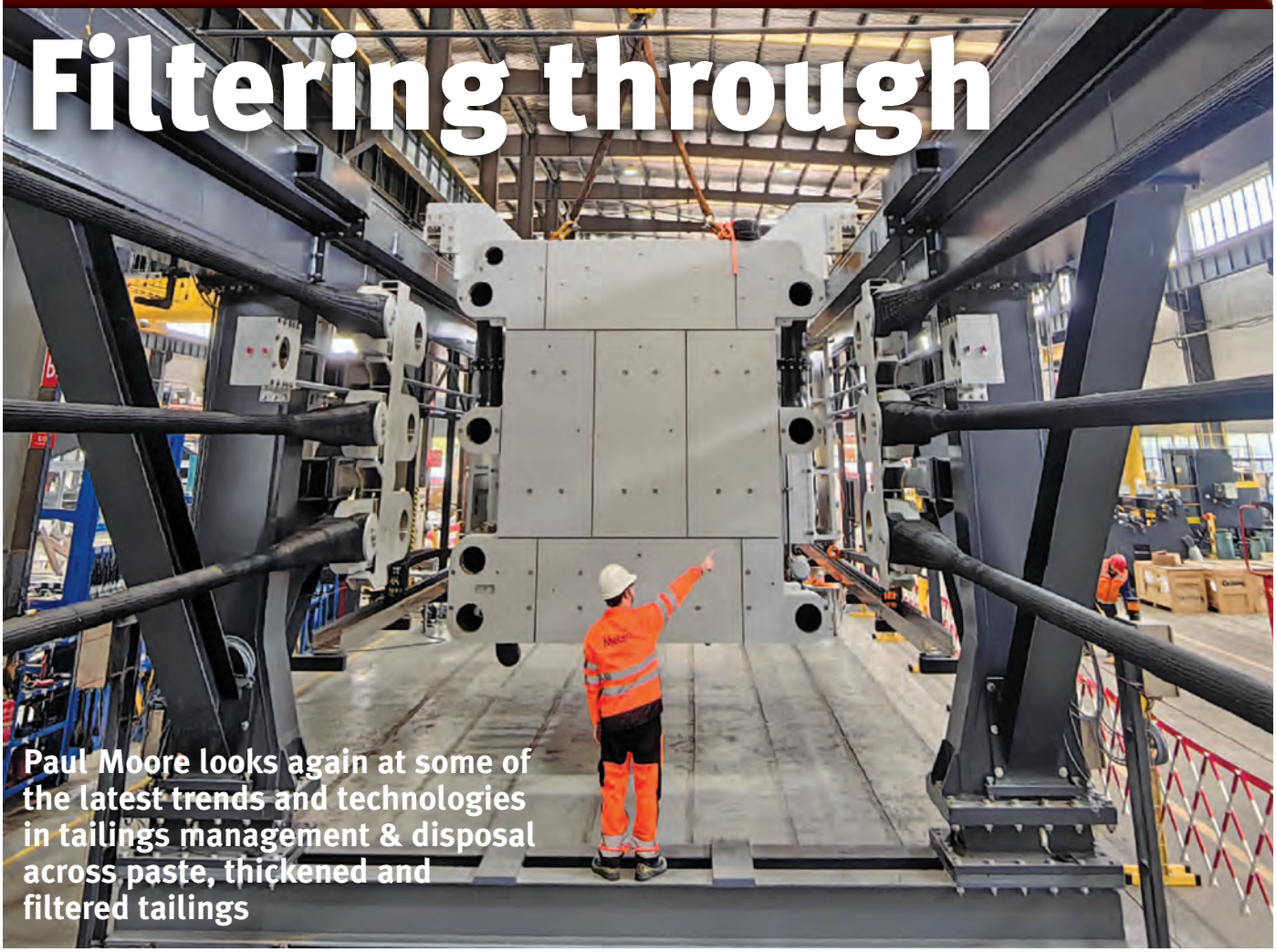


Paul Moore looks again at some of the latest trends and technologies in tailings management & disposal across paste, thickened and filtered tailings

In 2022, ICMM published the Tailings Reduction Roadmap, which lays out innovative approaches and solutions capable of significantly reducing tailings from the mine life cycle. It highlighted mature solutions that can be implemented in the short-term, such as coarse particle flotation technology (CPF) which enhances the recovery of coarser particles of ore, as well as solutions with the potential to reduce tailings in significant quantities, but will require further development over the next 10-15 years.

Erik Vlot, Global Tailings Process Manager and Job Kruyswijk, Slurry Solutions Manager at **Weir** say the company shares this commitment and is rethinking the basic assumptions the mining industry has about tailings. It is researching and developing innovative technologies and processes in a way that transforms the current value proposition and ensures more sustainable tailings operations.

They stated: "Weir Technology Hubs play a vital role enabling Weir to partner with miners to help them rethink, reduce and repurpose their tailings. They are centres of excellence, where various technologies and solutions for tailings management can be developed, trialled and assessed. We carry out extensive testing and analysis to identify ways to optimise tailings processing methods, reduce the amount of tailings generated and ensure it's a more manageable product."

Providing proof of concept for tailings solutions ensures that any recommendations made by Weir are substantiated with practical demonstrations that can be viably scaled up and remain effective. Weir also carries out sample testing, which includes a detailed evaluation of the pros and cons of proposed solutions, with a focus on the practical applicability in real-world scenarios.

Vlot and Kruyswijk: "These capabilities allow Weir to partner with miners to share its technical expertise, allowing them to make decisions about their tailings management solutions based on solid evidence and, as a result, ensuring a higher chance of successful implementation."

Weir Technology Hubs carry out slurry test work to determine the most beneficial overall approach. This means analysing specific components in the circuit and, from there, developing and validating flowsheet-driven bespoke solutions. At the facility in Melbourne, Australia, there is a particular focus on dewatering applications; it also has a pipe loop test facility that provides design in-puts to pipeline designers in order to de-risk their designs.

Additionally, Weir has the ability to test a complete cyclone setup, facilitating the thorough examination of Terraflowing™ flowsheets,

Metso's new Larox® FFP3716 pressure filter has the biggest plate made of a monoblock in the market

covering each stage from thickening and cycloning to centrifuging, mixing, pumping, as well as deposition tests and equipment sizing.

Through active development and testing of flowsheets, Weir says it is able to pinpoint inefficiencies and identify areas for improvement. "Weir Technology Hubs are key innovation centres for the mining industry and offer an invaluable resource where ideas and concepts rapidly evolve and mature and have proven to create meaningful changes that will help make mining more sustainable. Weir's engineers have expertise in site-specific design, developing bespoke pipeline transport, dewatering and separation systems based on operational requirements."

Different strategies exist for managing specific tailings streams and Weir told ***IM*** it works closely with miners to understand their specific challenges. It then works to identify the most beneficial solution.

The primary objective is often to de-risk operations and minimise uncertainties. "This process typically involves creating a clear understanding of achievable baselines and determining specific actions, such as utilising PD

Pipe loop test area at the Weir Technology Hub in Venlo, Netherlands

pumps or centrifugal pumps depending on the dewatering performance of the thickener. Weir then weighs up the trade-offs – including operational fluctuations – to establish a risk profile and assess both the capital and operational costs."

At the same time, if productivity targets aren't being met, alternative operational approaches can be explored. "This might include, for example, assessing the integration of new technologies to enhance efficiency. This phase primarily generates input data for further in-depth studies."

In essence, Weir says its testing methodology is two-fold: optimising existing processes by de-risking operations and exploring innovations to boost productivity. Ultimately, both these approaches facilitate informed decision-making in tailings management.

As an OEM, Weir is often at the forefront of the developments, which then inform many trends within the industry. One example of this is the Terraflowing™ process, a proprietary solution developed at the Weir Technology Hub in Melbourne, which produces an engineered tailings product in which the properties are tailored to meet the specific requirements of the Tailings Storage Facility (TSF).

This involves customising the water content to allow for pumping what are often significant distances, while also employing decision trees to determine optimal flow sheets, such as utilising cyclones for hypermobility zones.

Vlot and Kruyswijk conclude: "As the ICMM roadmap makes clear, many of the challenges that tailings present will only be solved with collaboration. For Weir, being a valued industry partner takes many forms – harnesses advanced technologies to provide customers with predictive insights into pipeline operation, enabling early detection of anomalies and optimising equipment efficiency, just to mention a few – but, importantly, these technologies, services and solutions fit within its broader commitment to help miners reduce their waste and produce a more manageable product."

Innovation in Tailings Dewatering – Anglo American & WSP

WSP's Mark Bruton, Mine Waste Europe Lead & James Purrington, Associate Tailings Engineer, last year outlined how the development of an innovative new tailings technology, hydraulic dewatered stacking, is advancing the mining industry's commitment to improvements in stability, water recovery and closure of tailings facilities.

Tailings is an area of mining where the industry is constantly seeking new approaches and ideas. They are an inevitable byproduct of the mining process but require extensive management to protect people and the environment. Recent catastrophic failures have rightly resulted in enhanced oversight and calls for change. Through the Global Industry Standard for Tailings Management (GISTM), mining companies are now actively adopting new levels of governance to increase the safety of tailings storage facilities (TSFs).

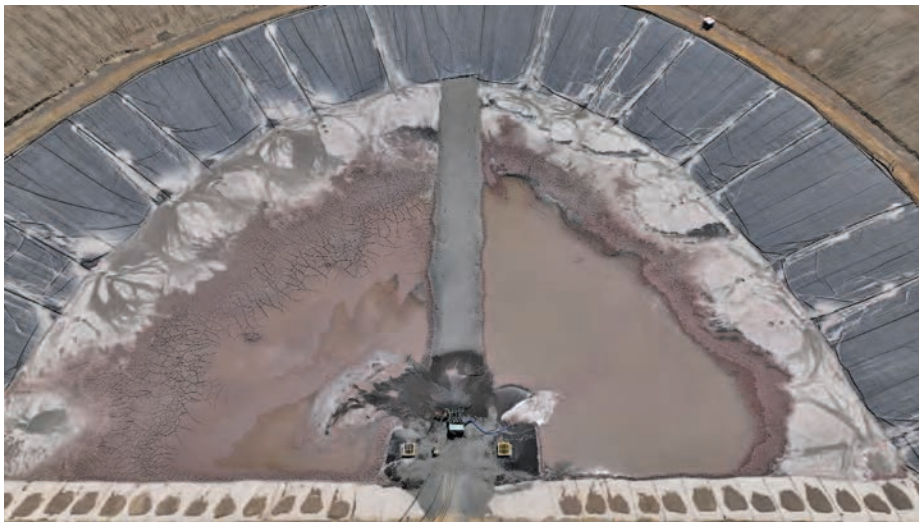
They state: "Governance alone is not the solution, however. Identifying new methods and technologies for managing tailings is imperative. Those methods must be robust, practical, and economical at scale; ideally, they should also minimise any increase in operational complexity at the facility. An innovative tailings management concept, hydraulic dewatered stacking (HDS), appears to tick all these boxes. It is being developed by global mining major, Anglo American, who partnered with WSP to conceptualise and design the new approach."

The idea for HDS was born out of the adoption of coarse particle recovery (CPR) at Anglo American's El Soldado copper mine in Chile. CPR results in a free-draining sand byproduct, which the mine believed could be put to beneficial use. Reaching out to WSP, Anglo American's question was a simple one: could this waste be turned into a resource? The answer quickly became a resounding yes.

The concept devised by the combined Anglo American-WSP team uses CPR sand as a filter, co-disposing it with tailings to deliver passive drainage and gravitational dewatering of the tailings. The water is then managed separately for re-use in the mining process.

The HDS concept thus delivers benefits well beyond just finding a use for CPR sand. The three main advantages studied relate to water, stability, and closure.

Conventionally deposited tailings contain a large amount of entrained water with supernatant water typically managed on the surface. This results in large amounts of water being lost through entrainment and evaporation: water losses from tailings are in fact the most



Hydraulic Dewatered Stacking (HDS) at Anglo American's EL Soldado operation in Chile

significant water loss at the majority of mining operations.

In contrast, HDS liberates the water entrained in the tailings and allows it to be recycled. This reduces demand for fresh water (or desalination), and therefore the overall water sustainability of the mine. In water-stressed regions, this is a significant benefit, not only for the environment, but also to the mine's bottom line, as the financial cost of water is expected to increase substantially over time.

By dewatering the tailings and eliminating the surface pond, HDS improves the stability and safety of tailings storage, a key element of the GISTM. Meanwhile, in the event an HDS facility does fail, the lower interstitial water content and surface pond volume reduces the potential for flow, and thus the potential area of inundation. The dewatered tailings simply do not flow well, making the large-scale mudslides associated with previous tailings dam failures a thing of the past.

They add: "HDS technology delivers this without the need to build a capital-intensive plant, as in other thickened and filtered tailings solutions. It is therefore able to offer similar benefits, at a fraction of the cost. The free-draining nature of HDS may also make the process suitable for tailings dewatering in tropical climates, which aren't well suited to the operational complexity of filtered tailings."

The interbedding of sands or installation of vertical sand drains within the tailings mass results in much more rapid consolidation than in traditional wet tailings impoundments, reducing the potential for large-scale subsidence over time. Tailings can also be deposited in cells, which facilitates progressive closure and reclamation over the life of the mine. Finally, because the HDS facility remains free draining after closure, the risk of re-saturation and long-term seepage of contaminated water is significantly reduced, even in areas of high precipitation, with reduced potential for groundwater contamination.

As a result, closure planning is simplified; there should also be less need for long-term monitoring campaigns. Repurposing of the land can be realised quickly and handover should thus be possible much more quickly at the end of mining operations.

Bruton and Purrington conclude: "Drawing on WSP expertise in mine waste, hydrogeology, advanced labs, pumping and pipes - to name just a few - the initial idea has been developed through a series of concept studies and lab trials and is now being tested in the field at Anglo American's El Soldado mine in Chile. Here the technology is being tested at large scale, with further research underway on the performance of the tailings, as well as closure trials. The early results are extremely promising, with excellent dewatering, consolidation, and water recycling rates already achieved."

The Diemme GHT5000F filter press at Toquepala remains the largest operational filter press in the world

They continue: "There is more to be done before HDS becomes a common feature at mines around the world. Data collected at El Soldado is now informing a second trial at a mine in South Africa, where the potential for conversion of an existing TSF to HDS is to be studied. There is also potential for benefits beyond those mentioned here, with the team studying whether the HDS facility could be used for carbon storage at closure, and other exciting potential post-closure land uses. The development of this innovative new tailings technology marks a step forward in the mining industry's commitment to improved safety and environmental sustainability."

Diemme Filtration evolving & expanding

In January 2024, filtration major **Diemme Filtration**'s new expanded capacity plant in Lugo was formally inaugurated. The investment primarily enables Diemme Filtration to multiply its current production capacity and cope with numerous challenging filtration projects involving large filter presses. ***IM*** caught up with Andrea Pezzi, Diemme Director of Marketing and Communication. He had this to say on the new facility: "The total area is 24,000 m², of which indoor factory space is about 12,000 m². Everything is now ready to start production including the new paint shop and sandblasting department. We have also updated the production flows from our old plant, in this way we are not just having more space for construction, manufacturing and logistics, but also have improved the flow and efficiency through increased automation and organisation with new systems in place to monitor the production steps." Pezzi said that while the new space will not necessarily be used only to build its largest GHT5000F Domino filter, it will give a lot more flexibility should several orders for that unit need to be constructed around the same time to do that and also carry on with other orders such as its highly popular GHT2500 filters.

Moving on to talk about the GHT5000F, ***IM*** has already reported at length about the first unit's installation at Southern Copper Corp's Toquepala operation in Peru, and Pezzi covered some information on progress during a presentation at the SME event in Phoenix. The DOMINO has now been running for more than a year, and Diemme Filtration during that time has been able to test it under design conditions which has seen regular throughput at 80,000 t/d at the required 85% dry or 15% moisture content. The cycle time had been predicted to be 15.5 minutes and in most cases the actual figure has been within 15 minutes. The unit passed its Site Acceptance Test in June 2023 and is now in full operation though currently it is only being operated 50% of the time, due to overall mine planning and scheduling reasons, and nothing to do with the capability of the plant which could run 22 or 23 hours a day if needed. The second DOMINO unit to be built is now in Chile awaiting assembly with a copper operation. Beyond that Pezzi said there has been significant interest in DOMINO from almost all of the big mining houses, some of which have had the chance to visit Toquepala to see it in action, plus other visits are planned. "It gives them real confidence to see that a filter on this scale can operate so efficiently."

Diemme Filtration continues to collect detailed data from the unit using its AIDA Service that uses IIoT Systems, of which the Toquepala unit is one of first global users. Its data is allowing Diemme Filtration to increase the strength of its overall database and optimise its filters globally

as a result and of course Diemme Filtration is sending the mine a monthly findings report including recommendations about the management of certain components. "With AIDA last year we were doing a lot of preparation of sensors and software as well as rollout itself and now it is fully operational at a number of sites – we expect it to be connected at 14 sites by end 2024. It is a very strategic and fundamental part of our plan and expected growth and a great efficiency tool for customers." The majority to date involves the larger units like the GHT5000F and GHT2500.

Beyond the GHT5000F, demand for the GHT2500 continues to be high. The unit for Pan American Silver's Huaron silver-zinc-copper-lead mine in Peru is now in final installation and will soon be commissioned. Pezzi said there are also a number of other contracts being finalised in both Peru and Chile. Another growing market is Indian iron ore; recently there was a commissioning of a Diemme GHT2500F filter press for iron ore concentrate at an operation in Odisha. Diemme Filtration sees this market as having major potential for growth.

Diemme Filtration is also positioning itself globally for growth with a focus on 'customer proximity' - opening or expanding business units in strategic areas to offer enhanced levels of sales and equipment service, parts warehouse storage and also testing. These hubs will also be a first point of contact so the customers in that region do not have to contact the headquarters to have issues resolved. A good example is the new facility it opened in Nova Lima, Brazil last September which now has seven permanent staff. In India, the sales and service facility in Ahmedabad, Gujarat, is being expanded and in Australia where its office is currently focused on sales, Diemme Filtration is looking for new sites where it can have a better service and parts presence. In some regions there is also the opportunity to grow through the network of sister companies within parent company Aqseptance Group. This includes the US where Diemme Filtration will be able to expand its presence at the Johnson Screens site in New Brighton, Minnesota.

The last point Pezzi stressed was its developing ESG strategy, which he is heading up. "For us its a very important step and we are proceeding with actions as well as just words. Plus of course this ESG focus is coming from our customers as well who are focused on ensuring compliance from their key suppliers. I am leading the carbon footprint calculation work across Diemme Filtration for Scope 1, 2 and 3 emissions. Of course our filtration products and solutions, through their role in enabling safer tailings dams and water recovery are helping our customers on their sustainability journey as well."

ANDRITZ's tailings assessment

IM spoke to Mario Gerards, Industry Director Mining & Minerals at **ANDRITZ Separation**, about his views on tailings processing evolution and how it is well placed the deliver comprehensive solutions

Q Mining is facing a real challenge as it moves away from wet tailings storage solutions towards other solutions like filtered and thickened tailings - how is ANDRITZ helping miners on that journey?

A Whether the challenge is to increase water recovery with lower energy consumption or achieve optimal yield - efficient separation is a crucial competitive advantage in the mining and minerals business. After a century of experiences, we at ANDRITZ know how to tailor our range of state-of-the-art technologies to meet the strict standards of our customers and find the best processing solutions. With state-of-the-art technologies, including decanters or horizontal vacuum belt filters, heavy-duty belt presses or hyperbaric disc filters and filter presses we ensure a uniquely configured tailings line to customers. Thanks to continuous systems for upgrades of existing processes, automation and maintenance-friendly design, our process audits support to identify the best opportunities for enhancing productivity, safety, and capacity for practically any tailings stream.

Q Thickeners and filters have been around a long time - how is digitalisation enabling better optimisation and efficiency of this equipment?

A The global minerals and mining industry is increasingly embracing digitalisation and electrification across multiple locations, driven by the trend towards greater efficiency and control. These advancements not only simplify operation and enhance process efficiency but also align with the proactive efforts of many users to meet the impending strict environmental and sustainability standards. An example of the advancement of our products in tune with today's state-of-the-art technologies is the ANDRITZ intelligent filter press. Our proven filter press automation solution combined with Industrial Internet of Things (IIoT) technologies allows the creation of new mechanisms and features that promise higher product quality combined with lower operating costs.

Mario Gerards

Q Every tailings operation is different - how are you able to bring customised solutions to mining customisation based on differences in throughput plus in the nature of the material being thickened or dewatered in terms of particle size?

A This is correct; there is no one-fits-it-all-solution. ANDRITZ provides various individual technologies, which enable us to respond on special product requirements. From new equipment and systems to upgrades of existing processes, our ANDRITZ experts help to identify the ideal mining and minerals processes to ensure excellent throughput rates of tailings streams all with low operating costs and maximum reliability. Our broad portfolio of dewatering solutions supported by our unique process simulation tools enable us to configure a processing line for tailings that is tailored to meet our customers specific needs. By investigating new and innovative methods for the safe management of tailings, as well as the automation and monitoring of remote facilities, we make sure that our customers are well-prepared for future advancements.

Q Some mining houses are also looking at how to recover valuable minerals contained in previously disposed tailings - what solutions can ANDRITZ offer in this area?

A Yes, we can also confirm this trend. In times when the proportion of valuable minerals within a newly explored deposit is becoming ever decreasing, this type of processing is gaining in importance. Whether it is a question of eliminating old historical tailings ponds or extracting valuable minerals, we are equally concerned. Together with industry partners, we develop smart solutions that enable the industry to get a different impression by historical tailings. Our dewatering equipment remains largely unchanged compared to conventional 'online' tailings applications. The main differences are in the upstream area, primarily in the (re)recovery and processing of the products.

FLSmidth on a new innovation in paste thickening

An interesting white paper from Fred Schoenbrunn, Antonio Accioly and Craig Gilbert of **FLSmidth**'s Thickener Group along with Francisco Reyes, Regional Product Manager, FLSmidth in Chile, discuss a paste thickening project at a major copper concentrator in Kazakhstan. The operation was considering adding a second full concentrator plant to double capacity.

Their existing high compression tailings thickeners were designed based on 65 wt% underflow but were only capable of producing 61-63 wt%. The TSF required earlier than planned expansion as a result. For the second plant, the customer requested 68 wt% underflow. Based on the design and performance of the existing thickeners, a design innovation was needed to ensure the Plant 2 thickeners would achieve the higher underflow densities. The paper reviews several projects that led to the development of the Inner Spiral Blade innovation, that provides the high raking capacity needed for high tonnage and high density paste thickening.

The authors state: "Development of higher underflow densities from thickeners has long been a goal of thickener designers. The factors that limit the underflow density are the mud retention time and the raking capacity. At higher underflow densities the mud develops a yield stress or resistance to movement, and is limited in its ability to flow hydraulically to the underflow outlets. Designs for 'high density' thickeners have existed for decades. In general, for higher underflow densities incorporate higher torque capacity, greater depth and mud retention time, and improved rake designs. Multiple new installations and retrofit projects have shown the limitations of the various technologies."

An FLS Deep Cone Thickener

They add that high density and paste thickeners have a chequered history with many of them struggling to achieve the densities they are designed for. Deep Cone Thickeners (DCTs) have had good success at smaller sizes and tonnages, proving the technology is possible, but large scale high tonnage machines have been more problematic.

A high density retrofit on a 65 m gold tailings thickener was installed at a Canadian gold producer and started up in 2016. This is a high tonnage thickener processing about 65,000 t/d. "Prior to the retrofit, underflow densities of 60-61

wt% were typical although the target was 68 wt%. The retrofit included adding 2 m of wall height and replacing the full thickener mechanism together with a new diluting feed system, higher torque capacity and low drag rakes. After the restart, the plant was able to increase the underflow density to 64-65 wt%. Testing showed that achieving 68 wt% should be possible with about three hours of mud retention time." This thickener has a dual floor slope with a 10 degree inner slope and 7.125 degree outer slope. These are relatively low floor slopes, typical for high rate thickeners where the underflow can flow hydraulically.

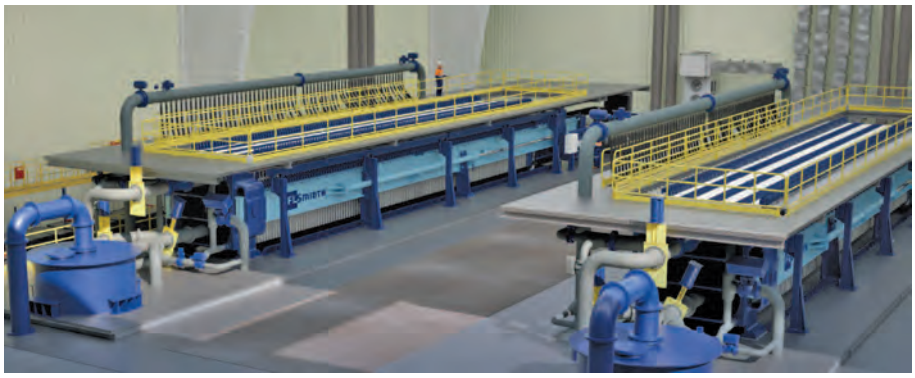
The new feed system on this thickener included E-Duc feed dilution to reduce the feed concentration from 40 wt% to 12 wt% for better flocculation. "This system works very well and resulted in greatly improved overflow clarity at lower flocculant dosages. The lower than targeted underflow density though has been expensive for the company in terms of requiring modifications to their TSF."

They add that mud transport within a thickener is dependent on several factors including floor slope and raking. At low underflow concentrations the mud generally behaves in a Newtonian fashion. As the concentration increases the mud begins to develop a yield stress, or resistance to flow. With Newtonian characteristics, the mud flows to the bottom outlets hydraulically. As the yield stress increases, that mud needs more force to get it to flow to the outlets. Deep Cone Thickeners designed for high yield stress muds use 30 degree floors to provide a lot of that force using gravity.

"One example of the difference can be seen at a northern Chile copper mine, where their latest 125 m tailings thickener has a 3:12 floor slope compared with 2:12 floor slope on their previous designs. This increases the mud volume and retention time as well as the centre depth. This change has resulted in a 1-2 wt% increase in the underflow density."

Another retrofit project with high density thickeners involved 3 x 60 m tailings thickeners at another copper concentrator in Chile. That project was originally built using box truss rake designs and these types of rake arms tends to build up mud within the rake structure. The rakes were replaced using a low drag tubular design that allowed the underflow density to improve by about 2 wt%, from 61-62 wt% up to 63-64 wt%.

The authors state: "Typical methods of improving the raking capacity involve using deeper and longer blades to move more material and cover more area. In looking at the raking capacity for the Kazakhstan DCTs, it became apparent that something else was needed to produce the results the customer was looking for.



FLSmidth has been seeing market success with its new AFP2525 filter with which it says customers can expect an average of 93% availability and up to 95% recovery of process water. AFP2525 filters for Buenaventura's San Gabriel are expected to be delivered by the end of July. Installation and commissioning will be in Q3 and Q4. Additional filters for Torex's Media Luna are scheduled for shipment in April with installation and commissioning also occurring in Q3 and Q4

Their High Compression tailings thickeners were only able to produce about 61 wt% underflow and they wanted 68 wt%. Just adding low profile rakes and steepening the floor would probably get them up to about 65 wt%, but probably not 68 wt%. To improve further, higher raking capacity was needed. A spiral inner blade design was conceived where the second rake blade was essentially shifted to connect the first and third blades on adjacent long and short arms, making for long spiral blades in the inner area that connect between the long and short rake arms. This effectively triples the raking capacity in the inner area."

CFD modelling for the mud bed was used in the spiral blade development to look at the mud bed retention times with and without the spiral blade and truss rakes. The results were very promising and resulted in a much tighter mud bed residence time distribution. This ultimately resulted in the adoption of the Inner Spiral Blade for the Kazakhstan DCTs.

"Thickeners are not particularly efficient or consistent in terms of mud retention time, meaning there is a wide variation in mud retention times. Some material typically ratholes, or short circuits to the underflow outlets very quickly. That material doesn't have time to thicken up and results in low underflow densities. Other material tends to stay in the thickener for long times, resulting in high yield stress and correspondingly high torque. By over-raking and improving the efficiency in the mud bed the thickener can operate with more even and consistent mud retention time, producing higher underflow densities while running at lower torques."

Rhosonics' SDM ECO

In the dynamic world of mining, efficiency, and environmental responsibility go hand in hand. One technology at the forefront of this balance is the new SDM ECO from **Rhosonics**, a non-nuclear density meter for slurries. Vitor Braz, Global Sales Manager, told ***IM***: "Traditionally, dewatering concentrated slurry – achieved via thickeners or filter presses – posed challenges in maintaining optimal density levels, and inline density meters enable real-time monitoring and controlling of slurry density. By continuously tracking density variations, operators can swiftly adjust parameters to keep density at the desired setpoint, maximising water recovery. This not only enhances operational efficiency but also reduces water consumption, a critical sustainability goal in mining."

He adds: "Moreover, proper density management is paramount for the safety of tailings storage facilities. Accurate density monitoring with the SDM ECO upstream from the tailing's disposal facilities helps prevent disasters such as tailings dam failures, mitigating environmental hazards, and ensuring regulatory compliance. In the quest for responsible tailings management, accurate density measurement is non-negotiable. With the SDM ECO, mining operations can navigate this challenge with confidence, safeguarding both their operations and the environment."

Rhosonics' new SDM ECO non-nuclear density meter for slurries

For processing about 85,000 tpd of copper tailings, 3 x 45 m DCTs were designed, sold and installed utilising the spiral inner blade technology. The Kazakhstan DCTs have been operating for several years now. "Considerable issues were seen initially as very large, unbalanced loads have occurred, causing multiple serious mechanical issues. The loads seen are significantly different from those seen with conventional large high rate thickeners. Initial work focused on reducing/optimising the flocculant dosage which helped but didn't solve the issues. Considerable mechanical reinforcements were installed, as well as armouring areas where abrasive wear was apparent. Current operation shows consistent ability to operate at the design 68 wt%. This compares with their Plant 1 High Compression designs achieving on average only about 61 wt%. Drive torques for these new DCTs are typically in the 5-15% range, significantly lower than typical DCTs operating at high densities. The low operating torques should allow for long life for the rake drive and mechanism."

Based on the results from the first installation, the northern Chile copper concentrator bought a spiral inner blade retrofit for one of their tailings thickeners which has been fabricated and installed and is expected to achieve similar operational benefits.

Stantec on turning mine waste into a revenue stream

IM recently spoke to **Stantec**'s Resa Furey, Director of Strategy and Market Development and Michael Stine, Senior Mineral Economist, regarding the tailings reprocessing world. They highlighted that mining companies regularly reprocess old tailings and waste materials as processing technologies and markets improve. With the increased focus on sustainability and market excitement for critical minerals, there is a new focus on turning Tailings Storage Facilities (TSFs) and waste rock into value.

Furey adds: "How might these 'human-made mineral deposits' be turned into mines of tomorrow? Re-using, recycling, re-mining and re-processing the material in TSFs and mine waste piles is the ultimate circular economy – taking waste and transforming it into a primary product creates value. Valorisation – the process of turning mine waste into something that has value - allows mines to contribute to sustainability metrics while improving their bottom line. Despite the promise, we have yet to see valorisation adopted on a significant scale. What's holding us back?"

She argues that tailings and waste valorisation projects face similar technical and financial challenges as typical mining projects. Technical challenges are solvable with enough money, the right equipment, good engineering, and, most importantly, new technology. Like most projects, the real hurdle then is the business case.

Stine adds: "Depending on the location of the mine waste, by-products (materials you extract from the waste and now wish to monetise) may lack proximity to a market. If there isn't an adjacent, local market, transporting by-products may be too expensive. In the case of aggregate by-products, if the local market is already well supplied, then producing more probably won't make economic sense. The geochemistry of the existing waste can present other challenges. Metals like arsenic or cyanide aren't allowed in aggregates or environmental fill products. Removing them (usually required to make the final product safe for reuse) may be cost prohibitive and can kill (financially) the project."

Furey and Stine also point out that reprocessing tailings to extract critical minerals, while potentially lucrative, can face challenges related to their product specifications and market size. Stine: "Take the cases of antimony or bismuth. Markets for both are small and low volume with few buyers and sellers with established relationships. Market information – about supply, demand and specific chemical forms required by the end users – is closely held and can be hard to get. The form of these minerals in the TSF may also not be compatible

with what sellers are used to receiving. As demand and markets for these minerals grow, new supply chains will result, and the market dynamics will change for the better.

Transparency and better information are the natural outcomes from a larger market."

Looking from the outset, when assessing tailings and waste piles, they say you should consider what has changed since the original mine plan or operation. Is there now demand for the by-products that didn't exist when the waste was created? Is there better technology allowing superior recovery? Are there additional ESG benefits of recycling materials?

Furey: "Tailings and waste valorisation are attractive when the TSFs or the waste piles have valuable, easily liberated metals, minerals, and by-products. Closed mines are especially good candidates for valorisation projects because reprocessing the waste won't disrupt the mine's primary operation and selling the by-products can help offset closure costs. Processing, separation, and extraction methods would have also improved dramatically since the plant was likely built. Thus, extracting more than the original targeted minerals is potentially economically feasible. Even with the value-add of critical minerals, the most attractive waste valorisation projects are often those that focus on the mine's primary metals. It's not a secret that tailings and waste piles at some historic copper and gold mines offer higher grades than currently operating mines."

Other projects have focused on waste rock and slag material which can be crushed and sold as an aggregate without the need to remove harmful chemicals.

The authors highlight the fact that valorisation projects that target minerals needed for the global energy transition are especially en-vogue. "For example, in 2021, Rio Tinto invested in adding a circuit to the Kennecott mine to recover tellurium (the essential component of cadmium telluride, a semiconductor used to manufacture thin film photovoltaic solar panels) from what would have been tailings. Because demand for tellurium is strong, the case for investment was obvious."

On another project, Stantec assisted in the development of a proprietary technical process to produce several sources of revenue from bauxite residue. This work included scale up, preliminary layouts and capital costs estimates for a demonstration plant. The success of the outcomes of this work will result in a long-term liability (bauxite residue) becoming a valuable resource, contributing to the circular economy, and having an environmentally beneficial outcome.

Finally, rather than reprocessing, some projects have focused on monetising tailings as a potential carbon sink. These projects show real economic and environmental promise. An example is BHP's Mt Keith mine.

Furey and Stine conclude: "For mining, a truly circular economy would mean 100% reuse of tailings and waste rock. It would mean that everything that is unearthed would have a pre-planned destiny. Given efforts to make the industry more sustainable, creating a truly circular economy at mines could be viewed as a reward in and of itself."

Four Diemme Filtration GHT2000.P7 recessed chamber pressure filters for coal fly ash filtration (two operating, two standby)

Paterson & Cooke on filtering coal fly ash

Jason Hamelehle and Casey Schmitt, both from **Paterson & Cooke**'s US offices, reviewed for ***IM*** an important filtration project for coal fly ash. Coal-fired power plants in the United States have come under stricter environmental regulations for their fly ash waste disposal, with some requiring the stored fly ash slurry to have no bleed water. Slurry with no bleed water is considered a paste by most definitions, and transporting paste can present significant technical problems. Instead, some coal-fired power plants have opted to filter fly ash and transport filter cake using conventional dry material handling methods such as trucking and conveying.

A power plant in the northwestern US has two active coal-fired generating units each around 740 MW output and producing approximately 2,800 t/d of fly ash. The previous fly ash dewatering system relied on thickening using high performance thickeners and pipeline transport with hydraulic piston pumps. An environmental agreement was passed to upgrade the fly ash dewatering system by 2022 to produce no bleed water. Paterson & Cooke teamed up with an EPCM firm to design a filter plant for truck transport and dry disposal of fly ash filter cake.

To meet environmental guidelines the fly ash had to pass the EPA Test Method 9095B Paint Filter Liquids Test, defined as no liquid passing through a mesh number 60 filter in a five-minute period. At the passing concentration of 25% moisture by mass the fly ash was a pumpable paste. To transport the material by truck, the transportable moisture limit of 18.5% moisture by mass would need to be achieved (moisture values defined as mass of liquid phase divided by total mass of mixture). The dewatering test work completed by Paterson & Cooke using in-house proprietary testing equipment was used to select recessed chamber pressure filtration technology to achieve the target cake moisture of 18.5% moisture by mass.

One of the design challenges was the operator required the filter plant to have 100% availability and 100% redundancy despite the additional cost, to avoid any bottleneck or shutdown of the filter plant that could impact power plant operations. To meet this requirement, four Diemme GHT2000.P7 recessed chamber pressure filters (two operating, two standby) were installed. When one filter is down for routine maintenance, one filter is still online standby, ready to come into service if one of the operating filters is unavailable.

The dedicated under-filter conveyors are reversible to be able to discharge to two independent take-away conveyors and loadout bins. If one of the take-away conveyors, or any equipment down stream of it, is down for maintenance, the under-filter conveyors change direction and deposit cake onto the standby take-away conveyor. This equipment ensures that abundant standby capacity is available to prevent long shutdowns but did not come without challenges. During commissioning and startup, excessively large piles would discharge in batches onto the take-away conveyor causing

overloading. To solve this, the dedicated under-filter conveyor speed and direction was optimised based on the relative direction of the cake discharge. For one direction, the conveyor runs faster at 9 m/min during cake discharge to spread the cake load and then decreases to 2 m/min to slowly discharge the filter cake onto the take-away conveyor. In the other direction, to spread the cake load the conveyor runs in the opposite direction of the cake discharge. Then the conveyor reverses towards the discharge point to discharge the cake onto the take-away conveyor. This retroactive optimisation ensured that the coal fly ash filter plant now operates as designed and produces cake that meets the environmental regulatory guidelines.

Dams and the mysterious 1.5 factor of safety

Bryan Ulrich, Owner of **Bryan Ulrich LLC - Tailings Solutions** and a well known figure in the industry having led tailings teams at Stantec and before that for many years with Knight Piesold, has discussed the issue that for dams and tailings dams, it is still almost universally accepted that for static, long-term, steady-state conditions a minimum safety factor of 1.5 is required.

Groups that are in agreement with this value include: The US Army Corps of Engineers (USACOE); The Australian National Committee on Large Dams (ANCOLD); The Canadian Dam Association (CDA); The Brazilian Standard ABNT's NBR 13028:2017; The US Bureau of Reclamation (USBR); and The Federal Energy Regulatory Commission (FERC).

Ulrich points out that the Global Industry Standard on Tailings Management (GISTM) does not actually provide recommendations for safety factors under any condition. Requirement 4.5 of the GISTM indicates that one should: "Apply design criteria, such as factors of safety for slope stability and seepage management, that consider estimated operational properties of materials and expected performance of design elements, and quality of the implementation of risk management systems. These issues should also be appropriately accounted for in designs based on deformation analyses."

This is quite similar to the advice provided by the USACOE (1970). That document uses the phrase 'factors of safety' or 'factor of safety' nearly 100 times, thus the importance of this factor is of considerable importance to the document. The document includes the following passage: "Appropriate values of computed safety factors depend on the: design condition being analysed; estimated reliability of shear strength design values; embankment height; presence of structures within the embankment; thoroughness of investigations; stress-strain characteristics and compatibility of embankment and foundation materials; probable quality of construction control; and judgment based on past experience with earth and rock-fill dams."

It adds: "In the final analysis, the consequences of a failure with respect to human life, property damage, and impairment of functions are important considerations in establishing acceptable factors of safety for specific projects." Ulrich says it should be noted that the same document recommends a minimum safety factor of 1.5 for static, long-term, steady-state conditions, but it is clear that the minimum value hinges on numerous factors that require special consideration.

Herza et al (2017) state: "The minimum acceptable FoS for dam design were anecdotally determined in the USA in mid-20th century by back-calculating the FoS of existing dams. It was found that the FoS of 1.5 provided sufficient contingency and was generally considered acceptable." Unfortunately, the authors do not provide a reference for this back calculation assessment.

Feld (1965) wrote (shortly after the mid-20th century): "A computed factor of safety of 1.3 for cuts and fills and 1.5 for earth dams is normal, although these figures are based on a number of uncertainties. These values are accepted however, because a factor of safety of 2.5 would make the cost of embankments and slopes so high that they would not be built." Shortly after that, Sowers and Sowers (1970) concurred that a 1.5 factor of safety was sufficient.

Regarding the field of aerospace engineering, which Ulrich says seems somewhat analogous to

Metso talks tailings treatment

IM caught up with Piia Suvio, Director/Head of Tailings & Water PG and Process Development at **Metso**, to talk through filtration and thickening trends & market changes and Metso's innovations and solutions which are helping address them

Q There is a lot of talk in the industry about very large filters as well as smart filters to help reduce overall footprint for very high tonnage operations plus optimise the dewatering process - what is Metso's take on the importance of a) scale and b) digitalisation when it comes to filters?

A You are correct that one of the reasons that we are going towards bigger filters is the reduction of footprint ie the floor area required but it also means more water savings. The upscaling trend – and the move to filtered tailings in general - is happening but maybe not as quickly as we thought it would. We at Metso also think there remains a market for thickened or paste tailings and that is not going to change – there are project suited to both and there is room for both. Back to the point on larger filters – our focus model for high tonnage tailings applications is the Larox® FFP3716 pressure filter which has a a 2,000 m^2 filtration area. It has the biggest plate made of a monoblock in the market – competitor filters use two plates that are bolted together. The feeding shoe in competitor filters is usually in the middle of the plate meaning usually there is manual work to make the shoe holes in the filter cloths – ours does not have that need so saves a lot of time. The way our filter is configured also means we can transport it in a normal ocean container. On your last question on digitalisation, the new Larox FFP3716 filter also has local data collection, and we can use this for in-depth analysis, for example statistical process control to understand the process better. We also carry out automatic weighing of the material and are able to analyse specific gravity and how much water has been recovered. All this can be used to optimise the filter operation such as the length of cycle and optimal moisture content based on the downstream filter cake handling process.

Q Filtered tailings have been seen a more costly option compared to conventional or even thickened tailings, part of which is due to a perceived requirement for conveyors. Is that view justified in your opinion?

A We see actually that filtered tailings can be the most attractive option when all costs and risks are considered. Firstly, I think it is important to talk about the water factor and in particular factoring in the price of water. Filtered tailings allows you to capture more water than other methods. So from that standpoint, in arid mining regions like Chile, the economics of filtered tailings can be quite positive. Secondly, in some places the regulatory demand is guiding the industry towards filtered tailings. Filtered tailings also tends to mean space saving. When we look at tailings projects we tend to look at the whole minesite and whole life of mine including volumes, storage requirements, service needs, topography and hydrogeological factors – and in some of these cases filtered tailings do come out on top. Finally I would say there is not the same bias against conveyors as before due to mines looking to reduce any kind of diesel haulage anyway, and they are of course electric.

Q On thickeners, how important are aspects like pre-engineering eg in your HRT-S solution, as well as modularity eg in your scalable Filtration Plant Unit in being able to meet current and future dewatering demand in the mining industry?

A With the Filtration and Thickening Plant Units (different types and sizes), we have productised the whole Plant Unit, optimising every step that we can – this includes shortening the engineering, especially the basic engineering. We have also pre-selected components and auxiliaries and planned in detail where everythng will be produced to really streamline delivery schedules. We have also optimised material take offs for the plant steel structures. We have found that customers and EPCMs also really like this 'black box' thinking of a whole flange to flange plant unit, as they can just work around it and feel confident that the Plant Unit will perform. As you say they are also scalable so we can add as many as are needed to reach the required capacity. Underlying everything of course is our past experience.

Piia Suvio

Q Until recently, paste and thickened tailings were touted as the future, with filtered tailings more recently being highlighted. From Metso's point of view, what is the right answers in terms of when each technology should be used and how much of it comes down to things like customer preference and climate?

A Paste and thickened tailings can be the right way to go – but it comes with some complexity in terms of getting the rheology right – if it is genuine paste or just paste-like, you have to have pipeline expertise and for disposal having the right beach angles and stacked geometry, for example. Paste pumping can also be challenging. The way we see it is that there any many factors that influence the right route. It can be very project specific, such as the particular concentrator plant set-up. There is no one right way – decisions just need to be based on thorough testing and looking at the site-wide details. Of course, the customer attitude to capex and opex spend is a major factor as well. It is also worth noting that a lot of tailings projects are related to mines which are running out of time with their existing wet Tailings Storage Facility, and due to permitting or safety reasons cannot build a new one or do more raises. Some mines are also looking to use filtration to reprocess their existing legacy wet tailings; while other like in the lithium industry want to reprocess tailings for remaining mineral content. Metso is working on several cases at study as well as delivery phases on all these types of scenarios for customers.

Q From a Planet Positive point of view how is Metso through its filters and thickeners ensuring that customers can maximise both water savings and reuse as well as energy savings?

A Water is a huge issue today and we have a lot of expertise in the water space. When we talk about dewatering, we want to ensure that the recovered water is handled in an optimal manner – where should or could it best be used or recycled, and do we have to treat that water. If it is being recycled to a specific plant process like flotation, we need to consider the water chemistry to see if that will have any impact. We can link water management in the process to overall production efficiency, including flotation yields and recoveries. Our big picture approach to tailings and water is one reason we are seen as a good and progressive partner by customers. With Planet Positive we compare our performance to any general accepted base performance in terms of water use and energy use, and then we look to quantify any benefits our approach is bringing with savings. With our thickeners we have optimised the flocculant use as well as the underflow densities with our advanced feedwell system. I would like to also mention that as the industry, including us, is looking at more use of fine and coarse particle flotation, we are focusing on what potential benefits the future flowsheet can bring from a tailings point of view.

dams in this case, Wikipedia (2024) states that, "the use of generally lower design factors is used because the costs associated with structural weight are high (ie, an aircraft with an overall safety factor of 5 would probably be too heavy to get off the ground). This low design factor is why aerospace parts and materials are subject to very stringent quality control and strict preventative maintenance schedules to help ensure reliability."

Ulrich concludes: "The exact origin for the nearly universal acceptance of the 1.5 safety factor for dams and tailings dams seems to have been lost to obscurity. More important than the adoption of a single and unique value, though, would be to combine the recommendations from the GISTM together with the advice from the 1970 USACOE document. I, personally, would also add recommendations to employ judgment, experience, assessment of uncertainty and consequences of failure while also employing 'stringent quality control and strict preventative maintenance schedules to help ensure reliability' when developing a site-specific factor of safety."

Schwing Bioset piston pumps at Aripuanã

Chuck Wanstrom, **Schwing Bioset** Director New Business Development, has outlined a major project it conducted at the Aripuanã mine, owned by Nexa Resources, in the state of Mato Gasso, Brazil. Aripuanã is a polymetallic underground mine that went through upgrades in 2022 that extend its operating life an additional three years, to a projected 14, with a nominal production target of 6,065 t/d.

Several mining methods are employed at the site including bench stoping, longitudinal retreat, and transverse stoping, as well as both cemented and paste backfill. As part of the backfilling operations, Nexa Resources enlisted the consulting engineering firm, Minefill Services, to issue a tender package to begin the procurement process for the paste pumps in 2019.

After evaluation of the received offers, three Schwing Bioset model KSP 220 H(HD)XL piston pumps were selected to deliver up to 150 m^3/h of cemented tailings at pressures up to 130 bar. The pumps are powered by 600 kW power units, each comprised of two 300 kW motors. The power pack systems also include a customised sound attenuation enclosure to limit sound levels while operating to no more than 85 dBA.

The dual motor configuration in the power pack provides redundancy as, in the event of an unexpected failure of a motor or hydraulic pump, the pump can continue to operate at half capacity with only half of the power unit functioning. This allows the site to either complete the pour or allow the pipeline to be cleared until repairs can be made.

The piston pumps are also equipped with Schwing Bioset's proprietary Ideal Control Circuit (ICC) technology that is internal to the pump design. The ICC is a dampening system that mitigates undesirable pressure transients in the pipeline that, are at times, observed with piston pumps by alternately ramping pumping speed down at the completion of a pumping stroke and gradually ramping up speed at the beginning of each new pumping stroke. This ramp up/down feature controls the material velocity in the pipeline and prevents the abrupt changes in material momentum that may otherwise induce water-hammer in the pipeline.

Another feature of the selected pumps is the inclusion of the optional Paste Flow Measuring System (PFS). The PFS will measure to within +/- 5% the volume of paste that has been pumped. This provides useful operating data that can be trended over time to schedule maintenance activities by tracking the overall performance of the pump and trending wear rates of replaceable components. The PFS also allows verification of the volumes of paste pumped to each stope to ensure the cavity has been adequately filled.

Wanstrom says that these features, combined with Schwing Bioset's reputation for high-quality reliable equipment and aftermarket support, made the pump selection an easy choice. IM