

Cu roundup

John Chadwick looks at the application of HMS, flotation developments, cleaning up conventional pyro metallurgy and some innovative technologies

We wait to see if Canada's biggest pure copper player First Quantum Minerals can succeed in its takeover bid for Inmet to become the world's largest copper producer. First Quantum has extensive copper and gold assets throughout Africa and nickel in Finland and Australia, while Inmet mines copper and zinc in Turkey, Spain and Finland.

First Quantum has said that the goal of the takeover is the establishment of the world's biggest and most rapidly growing copper mining company, with a projected output of 1.3 Mt/y by 2018.

This all came soon after Inmet lifted its estimate of copper reserves at its flagship Cobre Panama project by 27% and extended the projected mine life by nine years. This project in Panama will be one of the biggest copper mines to come on line in the next several years as well as the biggest mining project ever undertaken in Central America. Cobre Panama is expected to produce 300,000 t/y of copper.

Moving on, let's start by looking at ways to maximise heap leach operations. Joel Carrasco, Senior Civil Engineer and Engineering Services Manager at Ausenco comments on some of the key decisions around design, where new technology has vastly improved recovery:

"Heap leaching fits in well with many of the trends we see in mining today. Mining is being done in more remote parts of the world, where it is difficult and costly to locate and operate full milling operations, and also hard to recruit and retain skilled employees to run the operations and equipment.

"There is also a growing interest in smaller deposits, again, where it is difficult to justify the expense and timeline involved in a milling operation. New technology in heap leaching has increased recovery rates making them almost as viable as a milling operation for a fraction of the cost. Worldwide, there is more concern about energy costs that may rise, making energy-intensive extraction technologies vulnerable to

global oil and gas prices, while concern about carbon emissions also causes mining companies to look to less carbon-emitting technologies.

"On the side of heap leach, there have been improvements in application practices, geotextiles and other methods of keeping the solution contained, to improve recoveries and also to avoid potential contamination of the soil and groundwater.

"However, many mining companies find that heap leach operations sometimes do not run as smoothly as they could, with the recoveries they hoped for, or within a timeframe that meets their financial requirements.

"Experience has found that one reason is the different angles from which the teams that design the structures, and those that build and operate them, approach the project." This extends to how each group is evaluated and rewarded, and other factors such as working cultures, he explains.

"Teams that design heap leach facilities are dominated by engineers – both structural and geotechnical. They are motivated to build something that is going to be safe geotechnically, yet economical to build." This includes the slope of the heap and the network of pipes used to deliver the solution evenly throughout the heap, and then out of the heap for processing. "They want to be sure that the lining material is impervious and stays that way through the life of the operation, to maximise recoveries and to limit or eliminate releases to the soil and groundwater."

Engineers focus on good design and practice. "However, sometimes other considerations such as construction cost, cultural differences and the speed at which the operation can start to pay off its investment, are not held to be as important.

"On the other side, the teams that build and operate heap leach facilities are dominated by construction managers and metallurgists who have the same professional ethics but have different project drivers." They are evaluated

Heap leach pad construction at Lagunas Norte

and rewarded largely on their abilities to generate a return on investment. So, they make decisions based on "being able to build to the project timeline that will maximise overall recovery of metals from the ore, with a preference for generating early financial returns rather than later – while working within sound business practice, ethics, and environmental obligations."

So it is easy to see how decisions made at the design stage may sometimes not be made in a way that optimises financial return. "It might also be that build/operate decisions may be made in a way that is not best for the structural integrity of the heap.

"For a possible solution, it is useful to consider some of the lessons learned in the competitive world of electronics manufacturing. Historically, the design phase was done by one group, which would then 'throw it over the wall' for the Engineering team to figure out how to build, which in turn passed it on to Manufacturing. At the end of the process, Sales and Marketing would be tasked with turning the devices into cash that could fuel the next round of innovation.

"Some time ago, leading-edge companies found that if the various teams worked more closely together, the result would be designs that could be engineered, manufactured, marketed and sold with fewer problems. This can include group meetings in which all relevant departments and cultures are represented, cross-placement in which members of one team are seconded to other teams, and the appropriate use of current information technology to share information and news about progress."

Similar approaches can be used to improve the overall effectiveness and efficiency of heap leach operations. Some effective ideas are:

- Bringing Build/Operate team members into the design phase. This helps them understand more of the considerations that make for an efficient, stable design. It also helps the design team understand more about the importance of early, reliable and large recoveries to project financial viability. The design team will also learn more about how their decisions impact the ease and reliability of the operational phase – including how to avoid clogging the system with fine particles, and distributing application solution evenly or even worse, over-irrigating the heap
- Transferring design team members to work on build/operate projects can help them understand how their work can maximise recoveries, so their decisions are better balanced between structural and financial considerations. The design team also has a chance to spread its message of how operational short-cuts can endanger the integrity of the operation, and possibly the ultimate recovery of ore that is possible. The team can also understand the difference construction methods and cultures affect the building and operation of a heap leach facility
- More diversity in team meetings – getting people with different points of view into the same room together can go a long way in sharing issues and seeing each others' viewpoint. Team meetings need to include not just the decision makers but should include personnel such as the installers of the irrigation pipe network
- Leverage current information technology, which allows for a wide range of documentation about a project – designs, plans, timelines, critical paths, meeting notes, bid documents and other files – to be stored centrally and accessed easily via secure password. "As a result, there will be greater harmony throughout the wide range of professionals whose skills make up a team for an effective heap leach operation," he concludes.

Heap leach conveyor

A new high-speed impact cradle has solved problems with roller and frame damage from heavy conveyor loading conditions at an Arizona heap leach mine where two open pits feed a crushing facility with a capacity of 103,000 t/d. The customer estimates that the new cradles from Martin Engineering paid for themselves in just the first week of service, due to the savings in maintenance and downtime.



New cradles at an Arizona heap leach use Martin Engineering's Trac-mount™ technology to slide in and out easily for maintenance. The modular components are light enough to be removed by hand, without using a crane or other equipment to handle them

The mine uses bacteria to extract copper from the ore and SX/EW to recover copper from the resulting leach liquor. Crushed ore is delivered to a single leach pad by a series of overland and portable conveyors. At a transfer point handling -19 mm agglomerated copper ore with 20% moisture content, a 1,830 mm belt perpendicularly feeds a 1,524 mm belt from a straight 3.7 m drop.

The customer was using standard OEM impact idlers in the load zone; however, with the heavy loading conditions, maintenance personnel were forced to change an average of four to five rollers and one to two complete frames per month due to component failures. "The standard idlers simply could not withstand the heavy load and lengthy drop, costing downtime for repairs as well as the expense of replacement components," observed Martin Engineering Service Technician Doug Brown.

To address the problem, Brown suggested the newly-introduced High Speed Impact Cradles and installed the units shortly after. "After seven weeks of operation, approximately 2.9 Mt of material have been conveyed across the load zone, and there have been zero component failures," he said.

"The new rollers and frame are still in good shape, and it only takes one person to change the rollers when the time comes," said Brown. "The big problem solved is the downtime. In the past, when the customer needed to change the rollers or frame, they had to shut down the conveyor."

"The old style frame was difficult to remove. Maintenance personnel had to pull the arms down, then jack up the assembly, and only then could they pull it out. So the real cost savings

are in the greatly reduced maintenance and downtime."

"We wanted something that was slide-in/slide-out," added Martin Engineering Global Product Manager Chris Schmelzer. "These new cradles were designed using Finite Element Analysis, so we could confirm that they'd be strong enough, without having to overbuild them. We can make it as strong as it needs to be, without adding excess weight, so workers can remove and replace components without using heavy lifting equipment."

The innovative load zone design uses an elastomer bar suspension system that absorbs and distributes the material load being transferred, greatly reducing the stress on the idlers' rolling components and support structure. A design innovation (patent-pending) is the use of connecting brackets near the top of the idler frame to hold the three rollers together. These connector brackets are designed to allow multiple modular cradles to be tied together, so that the idlers throughout the entire load zone work together as a system.

Brown concluded: "This cradle is simple to install, and the easy access to the centre roller makes the maintenance a one-person job. In addition to greater durability, it's intentionally designed to facilitate service, making the task of changing rollers safer and easier."

Heap leaching lab evaluation

A number of heap leach failures have occurred in the past, many of which could be ascribed to somewhat empirical scale-up procedures. However important advances are also being made in the laboratory evaluation of ores for heap leaching, which reduces the scale-up risk. The availability of apparatus at laboratories such as Mintek in Randburg, South Africa, for the quantitative testing of the compression and hydrodynamic behaviour of crushed ores now places the specification of the combination of crush size, agglomeration/curing procedure and stacking height on a fundamental footing. Design engineers can now be provided with information on ore tested in the laboratory, of which the correlation with well and poorly performing industrial-scale heaps is known.

The international Percolation Leaching Conference held in Johannesburg in November 2011, organised by the SAIMM, drew percolation leaching presentations from around the world. A glance at the proceedings reveals the extent of innovation that continues to take place in the evaluation, control, modelling, design and scale-

up of heap leaching processes. This is no doubt being driven by the increasing reliance being placed on heap leaching as the grades of the remaining ore bodies all over the world continue to drop.

Heavy Media Separation

HMS is becoming more widely used in applicable ores, and advanced screening is a great aid to that. W.S. Tyler recently introduced a 3 m (10') wide version of its F-Class vibrating screen and says "the F-Class offers the only double eccentric screening solution for challenging applications that require minimal

The continual circular screening action provided by W.S. Tyler's F-Class's eccentric design also produces a constant, optimised G-force. Not only does this further maximise screening efficiency, it allows the screen to be an effective solution in both wet and dry applications. Designed for high tonnage outputs, the F-Class can process up to 1,200 t/h, as well as provide fast, accurate sizing. It can be run with up to three screen decks



vibration transmission during operation. This allows for the use of multiple machines within the same building or structure without the same reinforcing measures required to house traditional vibrating screens." Due to its consistent G-force, the F-Class is also known for its ability to keep screen openings clean, thus avoiding the pegging of material and making the processing of sticky material possible.

"It just made sense," W.S. Tyler President Florian Festge said. "Our double eccentric technology has been so effective that customers expressed the need for larger screens as their operations grew. Its size, paired with its versatility, make the F-Class a viable option for customers who were previously forced to invest in much more expensive technologies, such as exciter driven screens. For these clients, the F-Class offers reduced capital expenditures combined with enhanced screening performance."

This vibrating screen follows a tandem design. Two completely new modules measuring 3 by 3.7 m and 3 by 4.9 m were engineered. By forming any combination of these two modules, machine sizes of 3 m by 7.3 m, by 8.5 m or by 10 m can now be configured according to process needs. The F-Class, in tandem design, can also be operated at variable speeds and with different angles of inclination between the modules, thereby creating a banana type effect. The result is a fully customised screening system adaptable to meet the needs of almost any application.

The F-Class is ideal for screening situations that require consistent, load independent performance at constant G-force in all operational modes. Featuring unique and reliable, proven four-bearing technology, it minimises structural vibration and delivers a consistent stroke, which two-bearing or even horizontal screens cannot provide, the company says. "This means that, when equipped with the right media choice, the F-Class virtually eliminates blinding and pegging. With the ability to handle the toughest applications, copper is

one of the many ores the F-Class is designed and built to classify.

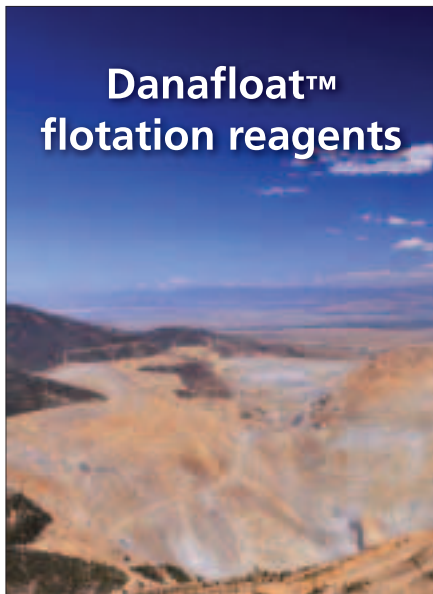
It features an advanced eccentric shaft design, supported by four high-performance, double spherical roller bearings. The double eccentric shaft creates a constant positive stroke that handles material volume spikes without losing momentum. As the eccentric shaft turns, the screen body is forced to follow the shaft movement. While it travels upward, the counterbalance weights move in the opposite direction and create an equal force to that generated by the body. As a result, the forces cancel each other, allowing a dynamically balanced system that transmits minimal to no vibrations into the structure. This allows multiple screens to be placed side by side while minimising the investments into heavy structures. Furthermore, the design keeps noise emissions low for a quieter system and reduced overall plant noise.

Cudoco is banking on innovative allmineral technology to process its native copper. In mid 2013, the Chinese state company Sinosteel will commission ten alljig® jigging machines to treat various particle sizes as an integral part of the Rocklands Group copper project. allmineral's technology will be the core equipment within this high-tech plant, which will produce high grade copper as well as marketable cobalt, gold, pyrite and magnetite concentrates.

allmineral's Project Manager, Andreas Horn, sees this order as "both, an acknowledgement of the capabilities of allmineral's technology and an essential step to enlarge its existing footprint in this important market". After performing tests on allmineral's pilot equipment (mini-jig and alljig® P-400) in independent laboratories located in Perth, Cudoco chose the allmineral technology.

During the first years, the focus will mainly be on mining high-grade ore close to the surface with an expected maximum Cu grade of up to 20%. In addition, copper sulphide and oxide with traces of gold and silver will be mined, along with pyrite with traces of cobalt, gold, and

Danafloat™ flotation reagents

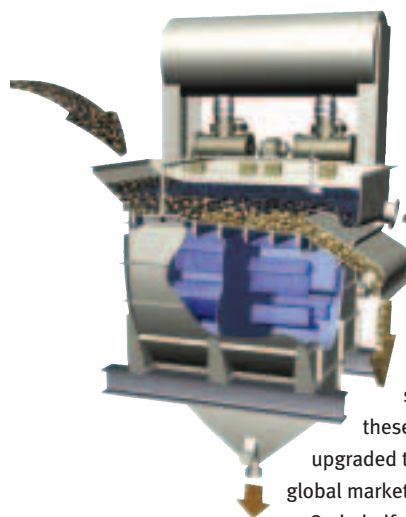


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alljig jigging machines are the most popular allmineral technology throughout the world with close to 500 units supplied to date. Their state of the art air-/side-pulsed design allows for optimised jigging stroke generation along with high energy efficiency. The alljigs in Queensland have an operational capacity of up to 740 t/h and produce a remarkable high grade concentrate, the company reports

silver as well as magnetite. All of these minerals will be processed and upgraded to high quality products for the global market.

On behalf of Cudoco, Sinosteel is building a unique processing plant where the alljigs will play a key role in the process. There are four coarse jigs (8 to 40 mm feed size, capacity of 110 t/h each) as well as three medium jigs (4 to 8 mm feed size, capacity of 55 t/h each) and three fines jigs (1 to 4 mm feed size, capacity of 45 t/h each).

Multotec HMS at Kipoi

A project report on Tiger Resources' Kipoi project in the DRC will be in the **IM** April issue. It is a great example of how effective an HMS plant can be. The stage 1 operation with just HMS and a spiral plant has provided cash resources for the company to move to the second stage of SX-EW.

Dean Lincoln and Roy Roche of Multotec Process Equipment (MPE) told **IM** about the supply of critical processing equipment for the project: cyclones (classification and dense medium), a magnetic separator and spirals.

Due to the nature of the material and flowsheet requirements from this operation, MPE supplied the dense medium cyclones, which are lined with engineered tiles to ensure optimal life efficiency. The ceramic tiles are manufactured by Multotec Wear Linings who manufacture these tiles specifically for the Multotec cyclone range. Lincoln noted that "each tile is specifically manufactured such that they fit tightly together ensuring that the gap between the tiles is optimal, making it more difficult for the tiles to fall out compared to traditional field cut tiles in other competing cyclones."

To ensure consistency in the supply of cyclones, Multotec recommended cyclones of similar diameter. This decision was primary to reduce overall stock holding levels at the plant. Where possible, the cyclones could also be interchanged amongst each other if the need arose.

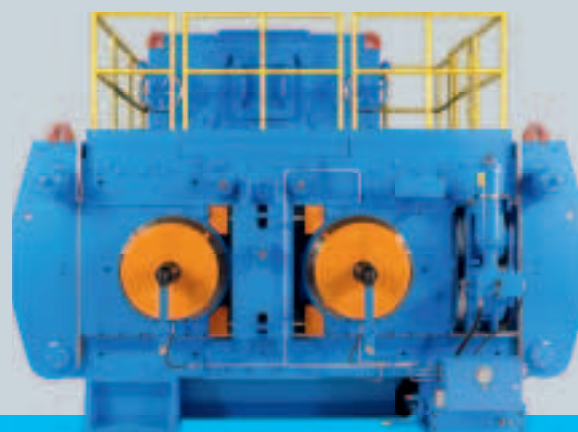
The 510 mm diameter DMS cyclone is equipped with PU vortex finders. The MPE spiral supply comprises of the SC20/7/B3 spirals. Three stages of spirals were supplied – rougher, cleaner and scavenger stages. MPE dewatering and desliming cyclones were also added to this supply to ensure complete spiral package supply.

The scavenger spirals feature one distributor with 24 outlets in a battery of 12 spirals; for the roughers, one distributor with 18 outlets in a battery of 10 spirals; and for the cleaners, one distributor to 12 outlets in a battery of six spirals.

The MPE hydrocyclones at the spiral plant are of types HA350-15-0/A-C45, HA250-15-0/A-A/55, HA250-15-0/A-D/40 and HA350-15-0/A-D/45 – two cyclones feeding the scavengers spirals, one feeding the roughers, one to the cleaners and one to the tails.

A Permax 150 m³/h capacity magnetic separator was supplied for the recovery of heavy media material. This has proven to be an efficient wet drum separator owing to the fact that its magnetic arrangement has been optimised to ensure a consistent Gauss strength across the entire length of the drum. The magnetic separator plays an important role in the dense

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Kipoi's HMS and spiral plants drew heavily on Multotec Process Equipment



medium circuit as it recovers the heavy media which is critical for all dense medium processes. Without an efficient wet drum separator, this medium will be lost to tailings.

All screening media to suit the vibrating screens on both the upfront and DMS parts of the plant were supplied by MPE. It is all application specific to ensure both non-blinding and effective screening characteristics bearing in mind life cycle requirements.

AmmLeach in the DRC

Alexander Mining reports that further to the signing last May of the Leaching Technology Licence Agreement with Metalvalue, excellent progress has been achieved, resulting in new opportunities. A new project company promoted by Metalvalue will build a commercial AmmLeach® copper/cobalt processing plant in the DRC.

Also Alexander will develop a batch testing pilot plant to be financed by Metalvalue to demonstrate AmmLeach in Kalgoorlie at the Western Australian School of Mines (WASM). The plant will have a nominal throughput of 1 t/d of ore (e.g. copper and copper/cobalt) and with the capability to produce up to ~10kg/d of cathode metal. Commissioning of the plant is expected in mid-2013.

This plant will complete the previous successful AmmLeach pilot plant work the company has carried out for copper at Leon in Argentina and, more recently, for copper and cobalt in South Africa. The WASM pilot plant will be suitable for testing large samples from around the world.

Several Metalvalue projects potentially amenable to AmmLeach are being investigated for major copper consumers in southeast Asia to develop copper deposits and securing the off-take of copper cathodes.

Metalvalue Capital Holdings (MCH) has been created as a new private equity vehicle dedicated to the structuring and financing of mining projects involving breakthrough

technologies including those of Alexander. Metalvalue will pay Alexander as a consultant and process engineer for all projects' capital expenditure associated with AmmLeach treatment plants.

Metalvalue has created a new special purpose project vehicle to establish an AmmLeach toll treatment plant in the DRC. It has secured an option on a suitable second-hand plant, which is planned to produce cathode metal with a capacity of 1,500 t/y of cobalt and 5,000 t/y copper. Metalvalue is securing a major supply of ore feed to the plant. Expected total capital expenditure is \$12 million, with a construction time of one year. The project work will entail considerable consulting work for Alexander, including test work and site visits. A major commodity trading company has agreed an \$80 million off-take agreement with Metalvalue. The plant will be jointly financed by MCH and other investors.

Mineral Engineering Technical Services (METS) has extensive experience in copper and last December acquired Contract Design and Management Services (CDMS), a leading provider of mechanical and structural engineering services.

Perth-based METS is a specialist consulting group that provides a range of services including, mineral processing, engineering design, training and specialist services to the mining industry. "In addition to organic growth we have chosen to acquire CDMS as it will strengthen our business and support our vision", said Damian Connelly, Director/Principal Engineering Consultant, METS. "This acquisition underscores our commitment to delivering quality well rounded engineering services and adds high level value to METS growing portfolio of global service offerings, allowing us to grow in a tough market."

CDMS comprises of engineers specialising in structural design, mechanical design, pressure equipment design verification, structural verification, maintenance, project management and product development.

Moving forward, METS and CDMS intend to work together on projects, pooling together their experience and expertise. "We aim to provide complementary service offerings that will provide great opportunities for both companies," states Connelly.

"I had a vision for providing mining with practical, superior engineering solutions," said Ben Pisano, Managing Director, CDMS. "Joining METS will accelerate that vision and give us access to an abundant wealth of resources and expertise."

New ideas in the DRC

Also in the DRC, old technology is being newly applied in copper, successfully. Most of FLSmidth's copper business has derived principally from south of the equator in the last few years, with a focus on global miners and the single-metal copper miners, as their projects tend to be very large and require the heavy, large equipment where FLSmidth is most competitive. Future copper mining projects are being designed for very large tonnages which increase the opportunities for FLSmidth supplied equipment. The company says it is "seeing that our customers are becoming more sophisticated buyers and are demanding more from fewer suppliers."

FLSmidth recently commissioned its Eimco® MRC Reactor-Clarifier™ technology at a greenfields copper mine in the DRC in what is being described as a "renaissance" of this technology. For more than half a century this technology has been used to remove suspended solids from water and wastewater. This MRC Reactor-Clarifier installation is the first of its kind in the DRC and the biggest in Africa to date.

"The introduction of Reactor-Clarifier™ technology in this mining application will set a



An SX-EW strip weir



An Outotec CellSense installation

benchmark in the African hydrometallurgical sector wherever SX is being used to recover any type of metal,” FLSmidth Hydromet Global Manager, Ron Klepper, says. “This technology minimises extraction losses and maximises the quality of the product being produced.”

Klepper, who is based in Utah in the USA and who was instrumental in the mine’s decision to install this technology, explains that metallurgists at the mine were experiencing high levels of suspended solids in the leach liquor — as high as 2,000 (ppm). This, in turn, led to the formation of ‘crud,’ a solids stabilised aqueous/organic emulsion that created imbalances in the SX circuit.

The original pin bed clarifiers had not succeeded in reducing the pregnant leach solution (PLS) suspended solids to levels that made it possible to meet the mine’s commitment to produce LME grade copper. The MRC Reactor-Clarifiers now enable the production of copper of the highest purity (99.9999%), which will attract a premium price on the world market.

“Although it is a far newer technology, pin bed clarifiers are limited by the fact that they are only successful over a narrow range of suspended solids and the levels at this copper mine exceeded this range,” Klepper continues. “A far more robust system was needed and, with MRC Reactor-Clarifiers already proven in other parts of the world, we had absolute confidence that the technology would meet, and indeed exceed, the mine’s expectations. This technology has a tremendous buffering capacity that absorbs any variation, both in start-up conditions and during day-to-day operations.”

The order for a complete ‘process island’ was placed with FLSmidth towards the end of 2011. Fabrication was carried out in South Africa and a sub-contractor installed the system on site under the supervision of FLSmidth representatives and the EPCM contractor during 2012. Klepper was on site in November 2012 to oversee the final mechanical check, which was

conducted according to the stringent FLSmidth Quality Assurance/Quality Control procedure, before the system went into operation.

The MRC Reactor-Clarifier solids contact units combine mixing, solids-contact flocculation, clarification and raked sludge removal in a single basin, achieving efficient removal of hard-to-settle suspended solids. A variable speed turbine maintains a

large volume of flocculated solids circulating within the feedwell and underflow is recycled to the feedwell to increase the solids concentration. The mixing, combined with an optimal solids concentration, greatly improves flocculation and effluent clarity. The larger, heavy particles settle out at a high rate and are collected by rake arms, while the clarified solution passes to the clarification zone for collection in a launder system.

The process of solids-contact flocculation enhances the settling rate of suspended solids and is well suited to a variable solids concentration feed, because the concentration maintained in the reaction zone — where flocculation takes place — is substantially greater than the highest solids concentration expected in the feed liquor.

“This project is an excellent example of FLSmidth’s ongoing commitment to identify technologies that have been proven in other industrial sectors and transfer them to the hydrometallurgical industry,” concludes Klepper. “This creates very low risk options for our customers. In this case, even though the MRC Reactor-Clarifier process is new to the base metals industry, we have a thorough understanding of its capabilities and have demonstrated this in the water sector over many decades.”

More SX-EW efficiency

Outotec’s CellSense electrolytic cell performance monitoring system enables early on-line discovery of deviations in electrorefining (ER) or electrowinning (EW) processes. The system detects aberrations in cell voltage levels or electrolyte temperatures which may be caused by short circuits, flow blockages, bus bar washing or other process or safety related causes. The system consists of a small CellSense sensor device, local cell status indicator (LIM), coordinator device, gateway, CellSense server and CellSense web interface. Each sensor device is able to measure two adjacent cells and is installed to the cell typically close to overflow. Sensor devices utilise wireless communication and are powered

by cell bus bars removing the need of frequent battery monitoring or replacement and guarantee high measurement sampling interval. These advanced features also make the system set-up and maintenance quick and light. For the tankhouse operators local indicator modules indicate cell performance problems and provide feedback of needed correction work conveniently at the cell simply with a few LED lights.

Based on the on-line measurement of CellSense devices the condition and performance of each cell are continuously evaluated with a model that estimates the optimum cell condition by automatically adapting to tankhouse’s state. Because of vast amount of on-line measurement data and changing process state the model is a key component from practical system utilisation perspective. It also removes the necessity of manually changing the alarm limits when the rectifier current is changed for instance. If abnormalities or too large deviations are detected, the information is instantly passed from the server to the local cell status indicator and to the CellSense web-interface. Therefore the operators are able to detect the deviations either from the field or from the control room. The CellSense web-interface provides fast on-line view to the refinery status and it can be accessed easily from multiple devices through secure connection. As an option Outotec can also offer mobile operator interfaces.

The installation of CellSense system can be done while the process is running and it has been proven easy and safe as the key elements are wireless and no installation of equipment is needed inside the cells. Detecting and locating the process anomalies in early phases allows focused reactions. “The CellSense system will identify the problematic cells in ER and EW processes and distinguish them from the cells that are performing close to the optimal level. As the operators are able to focus their work contribution on these low performing cells, the quality and overall current efficiency of the process will improve with decreased maintenance costs.” CellSense is used at more than 4 000 cells in Cu-ER, Cu-EW, Zn-EW, Ni-EW and Ni-ER processes around the world. This includes Rio Tinto (Kennecott Utah Copper) and Boliden (Boliden Harjavalta Oy Pori refinery).

Xstrata Technology has launched a new range of mixer-settlers designed for solvent extraction (SX). Xstrata Technology engineers have collaborated with Graeme Miller, principal of Miller Metallurgical Services (MMS). MMS is an industry leader in mixer-settler design with 25 installations worldwide of their side-feed mixer settlers, primarily for the copper SX-EW industry. More than 100 SideFeed mixer-settler units are in service.



The primary and secondary/tertiary mixers are designed for high efficiency; with specialized internal baffles and large inter-stage launders, allowing maximum mixing and enhanced mass transfer. Peak performance in the primary mixer is also based on a false bottom baffling innovation that permits problem free aqueous or organic recycle and operation in either continuity. The mixers have viewing ports and sampling points incorporated in the tank design. Removable mixer lids allow personnel access and unassembled agitator removal.

A smooth transition duct from the final mixer into the settler facilitates an ideal fluid distribution profile of the aqueous/organic emulsion across the full width and depth, eliminating vertical and horizontal eddy formation. The settler, with built-in picket fences and coalescing systems, has an improved macro flow pattern that leads to optimal separation of the emulsion, ensuring low entrainments in the exit streams. These design features are developments based on findings from experimental analysis and computational fluid dynamic modelling. The weirs at the discharge end of the settler are designed to control phase depths with close tolerance adjustments. Additionally, by modifying the plant layout, design approach and materials used in critical locations, fire initiation risks are significantly lowered, fire propagation is hindered and near-by equipment can be preserved in the event of a fire.

The company told **IM**: "The technology is tailored to a client's operation; catering from the smallest to the largest capacities. But regardless of scale, the Side-Feed arrangement offers the advantage of consolidated piping and control components on one side of the settler, with the organic and aqueous advance valves accessible from the mixer platform. High quality material of construction could be either stainless steel or fibre reinforced plastics, with superior corrosion life able to withstand the rigours of a low pH acid and chloride environment. Importantly, the modular design and small footprint, minimises construction time and capital cost. The design has the ability to ship entire settlers to site in a single shipping container."

Brendan O'Rourke, Project Manager of the SX-EW technology development, said a lot of work had been done in designing the Side-Feed mixer settler to take account of the deficiencies of alternative designs currently being marketed. "A mixer-settler works on the basic principle of the immiscibility of liquids, yet it is amazing how much time and copper loss results when equipment is not functioning optimally. Ask anyone in the industry, and their main concern is for a trouble free settler that doesn't need constant operator attention from crud build up or excessive organic entrainment. This is why we believe our use of the MMS SideFeed mixer-settler offers a big advantage to the industry."

Flotation

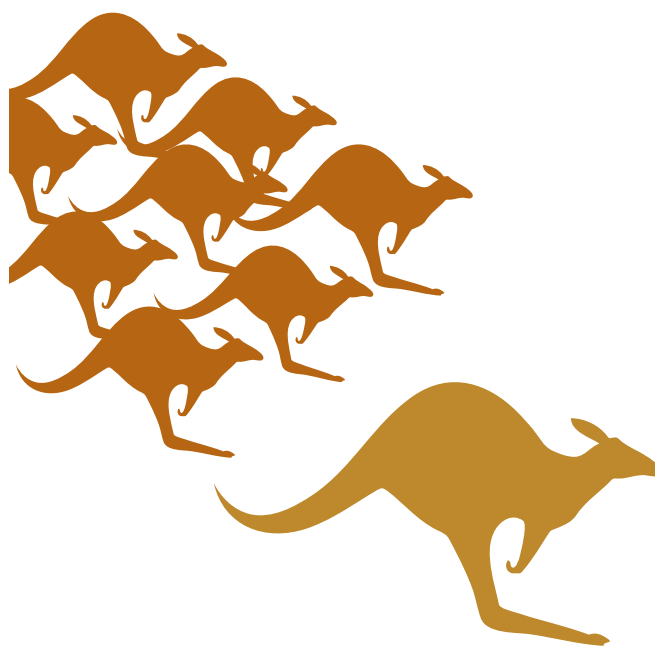
Cytec has developed AERO®7260 HFP, which it describes as "a highly efficient and versatile sulphide mineral depressant in diverse applications." In the Cu-Mo separation system, it functions as a selective Cu sulphides and pyrite depressant, intended to work as a partial replacement for widely-used reagents such as NaSH and Nokes.

NaSH has been the main Cu sulphide depressant used in Cu-Mo separations for many decades. Although it is an excellent depressant, it has the potential to generate high concentrations of H₂S, which is a toxic, flammable, hazardous, and smelly gas; therefore, NaSH poses several health and safety issues to the plant. There is the danger of stench and constant exposure of S compounds to plant personnel and to communities around the plants. The very high consumption (typically 20-40 t/d of 40% solution) is not only a safety hazard in the plant, but also a huge issue in logistics, as this warrants transportation of large quantities of this chemical to the plant. Usually, this entails several truck loads or train cars per week. This is a major problem for flotation plants both in urban and remote areas.

Despite the hazards and all the safety concerns associated with it, NaSH continues to be used extensively in Cu-Mo operations globally. This



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Cytec's versatile sulphide mineral depressant AERO7260 HFP will improve flotation plant health and safety

indicates that there is no robust and economically viable alternative available to the industry. AERO7260 HFP is Cytec's answer to this challenging issue.

AERO7260 HFP can significantly reduce the usage of NaSH by over 50% in the plant and because of its formulation it is a safer option compared to NaSH.

In addition to this, Cytec's ACORGA® range of copper extractants have a long history in the global copper solvent extractant market. The ACORGA OPT extractant series is a recent development. Cytec says "their enhanced metallurgical performance is being widely adopted by new and existing copper operations in the Copperbelt of Central Africa.

Nalco has been focused on developing improved technologies for base metals flotation. Building on its foundations in industrial water treatment and flocculation, Nalco is also leveraging the strength of Ecolab to develop customised products that solve specific flotation problems encountered in a variety of operations around the globe. Recent successes in copper/moly flotation highlight improved metallurgical performance for both metals. For primary molybdenite, a modification of the new reagent technology affords superior metallurgical performance while reducing reagent consumption and minimising volatile organic compounds. The same technology has shown unique ability to capture ultrafine molybdenite

that is not recovered using traditional flotation reagents.

According to Steve Paulson, General Marketing Manager for Mining and Mineral Processing at Nalco, customers are more frequently being challenged to maintain recovery with increasingly complex ores. Among the characteristics of these challenging ores are oxidation, high pyrite

content, mixed compositions, and high clay content. When encountering such conditions, froth quality and metallurgical performance can suffer when using traditional flotation reagents, he says. "Therefore, these circuits require flexible reagent programs and new flotation promoters that enable operators to quickly respond to changing ore conditions in the plant feed to flotation. This flexibility includes strong technical support from reagent suppliers such as Nalco with assistance in adapting and implementing the right flotation programs to help operators meet their production goals.

"In addition to flotation challenges associated with declining ore grades, water quality is also presenting new challenges to flotation operations. Increasing water demand is leading to insufficient quantities of fresh water, thereby requiring more frequent use of alternate sources of process water. These water

sources include seawater, brines, various sources of recycled process water, and brown water. The use of such waters in flotation circuits can lead to decreased froth quality and metallurgical performance. Therefore, the challenges in this area are likely to increase as well, and suppliers such as Nalco are focused on meeting these challenges. There is significant research work in progress to develop new flotation reagents that are more compatible with these new sources of water for flotation. Furthermore, the declining quality of water creates new challenges for protection of pipeline and plant assets. Operators and engineering firms are looking to companies like Nalco, with good experience in corrosion protection, to provide programs to help protect these assets."

AMIRA has embarked on a project that aims to validate and scale-up an innovative new technology – the NovaCell™ - for the flotation of coarse particles (+150µm). Extensive laboratory work has shown that the NovaCell is capable of extending the upper limit of flotation by a factor of five compared with existing technologies, without compromising the recovery of fines.

The implications of improved coarse particle flotation recovery of the magnitude demonstrated by the NovaCell is to reduce the specific comminution energy requirement by 20-30%, as well as to achieve significant operating cost savings through reduced grinding media consumption. These specific energy savings can be used to achieve a throughput increase (of 20-30%) for the same installed comminution power.

This is a technology development from Prof. Graeme Jameson who has a long history of innovation in the flotation field. After discussions between AMIRA and several potential sponsors, it has been decided that it would be also valuable for Xstrata Technology to provide technical advice to the project. If Phase 1 is successful a formal assessment will be undertaken in conjunction with sponsors to identify a commercialisation partner for Phase 2.

This proposal is likely to be of interest to sponsors who are owner-operators with significant flotation installations (in operation or under development) treating ores that are amenable to the NovaCell technology.

AMIRA regards this as "a potentially game-



Warman froth pumps are designed with a large oversized inlet with unique impeller inducer blade that can handle heavy froth and higher viscosity dense slurries with ease



The new NCS oxygen plant at Tsumeb

Pyrometallurgy sustainability

Turning to traditional metallurgy and clean up of copper pyrometallurgical installations, Outotec and Namibia Custom Smelters (NCS) are working together at the historic Tsumeb facilities in the north of Namibia. They have agreed on the

design and delivery of a gas cleaning system, sulphuric acid plant and related technologies downstream of the existing copper smelter. The total value of the contracts is some €130 million.

NCS is a subsidiary of a Canadian-based international mining company Dundee Precious Metals (*DM*, October and November 2011). It operates an Ausmelt copper smelter on toll treatment basis in Tsumeb.

Outotec's scope of delivery includes the basic and detail engineering, procurement and supply of a gas cleaning system and sulphuric acid plant, an effluent treatment plant as well as a sulphuric acid tank farm with rail and truck loading station based on proprietary Outotec technologies. The acid plant is expected to produce 230,000-320,000 t/y of sulphuric acid. Outotec's delivery also includes two Peirce Smith converters, equipped with high efficiency converter hoods for maximising the sulphur dioxide and impurities capture at the converters. The project is scheduled for completion in the third quarter of 2014.

The new gas cleaning system and acid plant will process the off-gases from the copper smelter and the converters. NCS determined that the acid plant was the best solution to capture and process the off-gases and, in turn, reduce emissions and considerably improve working and living conditions around the smelter. The acid produced from this plant is expected to be sold to domestic and international markets primarily through long-term off-take agreements.

"This project demonstrates the width of our technology portfolio and capabilities for providing sustainable solutions to our customers. We supply the entire chain of Outotec technologies and services to complement the existing Ausmelt smelter, which also nowadays belongs to our technology portfolio. With our integrated solutions Namibia Custom Smelters will have a worldclass process

plant that will meet the World Bank's environmental standards", says Outotec CEO Pertti Korhonen.

NCS worked hard last year to improve emissions controls, environmental performance and operational efficiency. Key projects include:

- Construction of a landfill facility for the safe disposal of baghouse dust and other waste from the smelting process
- Projects to reduce dust emissions from the reverberatory and convertor furnace section, which include increasing baghouse capacity, upgrading the taphole fume extraction systems, and improving ducting and fugitive fume collection
- Projects to reduce emissions from the Ausmelt furnace, which include installing new baghouse dust collection equipment including dust-removal, installing new ducting and other gas handling equipment
- Construction of a new dust transfer system, upgraded roasting and fume management facilities, enclosed storage area, bag-filling station and extraction system at the arsenic plant, all aimed at reducing the dispersal of dust.

A second oxygen plant has been commissioned and increases the smelting capacity of the Ausmelt furnace to 240,000 t/y from its previous capacity ranging from 170,000 to 200,000 t/y depending on the types of concentrates smelted. Total capital expenditures for the year 2012 at the smelter were estimated to be some \$60 million for environmental and plant optimisations projects.

In addition, an electric holding furnace is to be installed to temporarily store and upgrade copper matte until it can be transferred to a converter furnace for final processing. Based on a feasibility study completed by Hatch South Africa, the capital cost is estimated to be \$66 million, which includes a \$10 million contingency. Engineering design is commencing and construction is expected to commence in the second quarter of 2013, with a targeted completion date of late 2014 or early 2015.

NCS says "the project is expected to generate an attractive return based on operating cost savings of approximately \$5 million per year, capital expenditure savings of \$10 to \$15 million over two years, with ongoing sustaining capital savings, and improved metal recoveries of approximately 1% to 2%. Additional benefits include near-zero emissions and the eventual decommissioning of the current slag mill and reverberatory furnace, which further improves the long term sustainability of the smelter."

Resin-in-pulp

The overall copper recovery can be increased significantly by using resin-in-pulp (RIP) technology. This is especially true for ores with

changing mineral processing technology." The objectives of Phase 1, of 12-month duration, are to:

- Test the amenability of sponsors' ores to the NovaCell technology
- Demonstrate the technology on an operating plant(s) at pilot scale (nominally 1 t/h)
- Develop the initial designs of commercial scale NovaCell.

Companies supporting this project will have the opportunity to develop the capabilities to successfully scale-up the NovaCell to commercial-scale i.e. 100 and 1,000 t/h nominal ore throughput, and then such cells will be designed, fabricated and demonstrated on a site(s) selected by sponsors.

Weir Minerals' family of Warman® froth pumps are specifically designed to handle heavy froth and dense slurries in the flotation process. A stable pump can maintain a consistent flow-rate of raw material through the process, but it has to manage the flow of froth. Too much froth, and the pump can air lock, stopping production.

Since every mining site has unique raw materials with specific properties it is important to select the right froth pump to use due to the fluctuation in the Froth Volumetric Factor (FVF), the volume of froth produced. Design features of the Warman Froth Pump:

- Existing Warman AH series pumps can be converted with only a few modifications
- Standard froth pumps from the Warman AHF, LF, MF ranges for Froth Volumetric Factor (FVF) up to 1.8
- Upgraded froth pump AHF, MF, LF with Continuous Air Removal System (CARS) for FVF up to 4.0
- An inducer blade impeller for positive froth feed
- Enlarged high efficiency slurry throatbush to maximise the inlet size and reduce NPSH required
- Available in various discharge sizes.

poor filterability, where a large portion of the leached copper can be lost to the tailings, due to the poor solid-liquid separation characteristics of these type of ores. This copper can be economically recovered via RIP, since the resin is mixed directly with the ore, omitting the need for expensive solid-liquid separation processes. RIP can be used for both primary recovery of the copper from leached slurry, or for polishing of thickener underflows and tailings. According to resin supplier Puroilite, advantages of base-metal recovery by direct contact between the resin and the pulp include:

- reduced cost, since solid/liquid separation can form a large part of the capital cost of a project, especially in the case of pulps with poor settling characteristics and/or poor filterability: the use of RIP will reduce or completely eliminate this requirement;
- higher overall recoveries of the valuable metal as lower discharge metal concentrations and reduced soluble losses can be achieved than in the case of conventional filtration or solid-liquid separation systems;
- increased revenue;
- environmental: the use of RIP can ensure that waste pulp streams meet environmental specifications.

An iminodiacetic acid resin, such as the Puroilite S930 is used. This type of resin has a good selectivity for the valuable base metals of interest (copper, as well as other base metals such as nickel, zinc, cobalt) over calcium and magnesium. This makes it possible to use (relatively cheap) lime for pH control during adsorption without incurring very high calcium loadings on the resin. High calcium loadings will reduce the capacity of the resin for valuable copper and also result in the formation of gypsum (calcium sulphate) during elution with sulphuric acid, causing blockages. Another advantage of this resin is that it is easily stripped with sulphuric acid, which is readily available and relatively inexpensive.

Puroilite comments: "Due to the selectivity of the resin for ferric iron over the base metals of interest, it must be removed prior to the base-metal RIP step in cases where iron is present at high concentrations. This will reduce the degree of iron co-loading on the resin, which is important to limit the capital and operating costs. An RIP plant can be operated in either a carousel or continuous mode. In both cases, the flow of resin and pulp is counter-current with the barren pulp continuing to effluent treatment, after which it is discarded. The loaded resin is separated from the pulp over a screen and continues to the elution plant. A concentrated eluate is produced, which can continue to downstream processing, such as electrowinning, to produce high-grade copper."



Tenova Bateman Technologies is now performing the first commercial installations of Turbulent Technologies mixers

Copper waste streams

Wastewater treatment company BioteQ Environmental Technologies has its core expertise in sulphide precipitation technologies, BioSulphide and ChemSulphide. The group has successfully applied these technologies at sites around the world, including active copper mines. Dexing is an active copper mine in China that produces 150,000 t/y copper. As part of the open pit mining operation, low-grade ore waste dumps generate copper-laden acid mine drainage containing an average of 149 mg/l of copper. To treat this wastewater, a ChemSulphide water treatment plant with a design flow of 1,000 m³/hr was built in 2008. On average the plant treats more than 7 million m³ of wastewater annually and reduces the copper concentration to <3 mg/l. At the same time, the plant recovers close to 800 t/y copper.

BioteQ has developed and is currently testing an alternate process for treating arsenic- and copper-containing scrubber purge streams using its BioSulphide sulphide precipitation technology. Copper and arsenic can be selectively precipitated as separate copper sulphide and arsenic trisulphide precipitates, producing a final effluent containing < 1 mg/l dissolved arsenic for final disposal or recycle. Recovered copper sulphide can be reprocessed back through the smelter for value recovery, while the precipitation and recovery of arsenic sulphide can significantly reduce sludge volumes and handling costs, when compared to lower density arsenic hydroxide.

Turbulent Technologies mixing system

Tenova Bateman Technologies offers the Turbulent Technologies mixing system with the purpose of significantly reducing entrainment losses in SX plants.

Mixing and separation are the two conflicting goals that copper SX plants deal with every day. Intensive mixing will obviously provide better mass transfer (and stage efficiency). However, high energy mixing has always caused numerous operational problems that affect the bottom line. Settlers are designed to separate the dispersion after mixing, but even high performance settler designs (such as the Bateman Reverse Flow Settler) are highly sensitive to flow rates, and the characteristics of the dispersion produced. The more intensive the mixing, the harder it is to fully separate the organic and aqueous phases in the settler and reach desired entrainment values. Small droplets present in the mixing tank help form strong emulsions that do not separate well, even with the long residence in the settler. Crud formation is also encouraged by the presence of small droplets and air bubbles in the dispersion. Plant operators continuously have to compromise amongst the numerous factors such as PLS loading, production commitments, deviations from steady-state, changes in PLS (ore) composition, contaminants, etc.

After years of research into mixing, extensive testing and on-site pilots, Tenova Bateman Technologies, part of Tenova Mining & Minerals, is now performing the first commercial installations of Turbulent Technologies mixers, which are being retrofitted at several different plants around the world. Tenova Bateman Technologies is replacing existing auxiliary mixers in-situ, in order to increase mass transfer and solve problems of high entrainment. For the first time, the company told *IM* that there is no need to compromise performance between the mixer and the settler. Because replacement of the mixing tanks themselves is not necessary (only the internals require replacement), installation of Turbulent Technologies mixers is easily performed during a routine shutdown.

Dispersions treated with Turbulent Mixing in the auxiliary mixing tank provide optimal mass transfer (close to the theoretical limits), and separate more quickly, more easily and more completely in the settler. For a plant producing 40,000 t/year of Cu, an increase in 0.5 % of extraction efficiency (such as from 93 to 93.5%) means increased annual production of 200 t of Cu. Extensive on-site testing has shown that Turbulent Mixing consistently delivers a greater than 50% reduction in entrainment, and provides very stable and consistent performance even when process parameters are changed. This is of enormous benefit to plant operators. *IM*