

Floating ideas

Ailbhe Goodbody examines the latest trends in flotation in the mineral processing industry, and finds out what's new from flotation equipment and chemical providers

Flotation is one of the core mineral processing technologies and has become more pre-dominant as grades decline and ores become more complex. An ongoing trend in flotation for many years has been the need to process lower quality ores as a result.

Eriez's HydroFloat separator is designed for coarse particle mineral concentration

It is well known that ore grades are declining as a general trend across the mining industry and all mineral types. "To be able to meet production requirements, mines are installing larger and larger flotation

cells and more complex circuits," says Nikolas Zwaneveld, global marketing manager for mining's metals segment at Nalco Water. "Nalco has focused on developing stronger frothers that are able to lift coarser particles in these longer residence time systems, while still maintaining high froth mobility.

"Ultimately, to be able to meet the needs of the industry there needs to be close collaboration between the mines, equipment manufacturers and reagent suppliers."

As the easy orebodies are exhausted, the remaining mineral deposits are also more complex. As a result, meeting purity and grade requirements of downstream customers is becoming more challenging.

"We are seeing more and more selectivity-based issues whether it be pyrite and talc entrainment, or ash content in metallurgical coal," notes Zwaneveld. "This causing two main effects – firstly, mines are installing more complex flowsheets that include advanced processes such as ultra-fine grinding. Secondly, there is a greater demand for speciality reagents that can efficiently recover the desired mineral while rejecting more of the undesired mineral gangue."

Another trend in flotation is the recognition that true optimisation requires a holistic approach to managing improvement. "Looking at changing a reagent or adding a piece of equipment independently of these effects on the rest of the circuit usually doesn't really provide overall improvement," says Frank Cappuccitti, president of Flottec. "In order to truly optimise a plant, a thorough understanding of the chemistry, physics, geometallurgy, operating strategy, circuit configuration and equipment as well as operation training and education are important to achieve true improvement.

"Companies like Metrix that can provide all these services in one program will become the norm in mining in the future. When you take a holistic approach, this also leads to better leadership and management of the people in plants as they clearly know the program and their responsibilities that can be measured over time."

Another area being looked at by many companies involves using new hydrodynamic understanding of flotation to optimise reagents, operating parameters and process control. "This new technology is leading to the increased development of new sensors that can measure variables that before



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A high-capacity flotation technology, Eriez's StackCell has been developed as an alternative to conventional and column flotation machines



were unable to be measured," explains Cappuccitti. "Areas like froth and air recovery, gas hold ups, froth equilibrium heights, bubble size and froth volume creation will be measurements that will be available to be used to help have real time control of the flotation circuit. As we get better control of the circuits, we will be able to develop better reagents as we will have much better data to be able to improve the chemistry."

It is important to note that one type of flotation equipment is not appropriate for a complete concentrator and it is necessary to implement specific machines to meet specific needs.

"We consider efficiency, advanced process control, and safety as some of the most important trends in mining," says Max Howie, global product manager, flotation at Metso. "Metso continues to develop our flotation equipment to advance these very important topics."

Sustainability and making better use of water are also important trends in flotation. The desire to increase the sustainability of mining operations and the value chain, whether mining metals, industrial minerals, or fertiliser feedstocks, reflects the trend of attitudes in society as a whole. Major mining companies and their suppliers now have annual sustainability goals, reporting on sustainability in their annual reports, and in many cases have added sustainability roles such as sustainability officers.

Pablo Dopico, global technical and business development manager, industrial minerals and fertilizers at

Clariant Mining Solutions, suggests: "This focus on sustainability reaches all aspects of the mining operations, and flotation is no exception. In fact, sustainability has been the driver for the efforts at mining operations that use xanthates to replace them with other chemicals that are safer to handle and generate less waste."

In terms of access to water, mines are being built in more and more remote locations and access to water is becoming critical for both mineral processing and the social licence to operate. Zwaneveld says: "Nalco Water is working with mines across the world to make sure that they have access to enough water to operate through reduce-reuse-recycle as well as responding with reagents that work effectively in heavily recycled water or in alternative water sources like seawater."

When looking at the other trends, large data processing companies are trying to enter the mineral processing industry and looking at analysing large sums of data to find trends. "So far, the hackathon and big data approaches have not been very impressive in their results," declares Jeff McKay, product manager at Metso. "This is due to the complex and plant specific nature of flotation with few measurements that track ore type."

"Mines are talking about connecting mine geo data to concentrators and vice versa to permit better control strategies and optimisation of the entire supply chain. This is still in its infancy but shows promise."

PRODUCTS AND PROJECTS

There are a range of companies that make flotation equipment or reagents for the mineral-processing industry. *Mining Magazine* speaks to some of the main players about mining projects that they have recently supplied, as well as recent product releases.

Equipment

Eriez Flotation Division

Eriez Flotation Division now has one commercial application of its HydroFloat technology for coarse particle mineral concentration, and two demonstration plants underway (the company defines demonstration-scale as a single HydroFloat at the largest commercial unit size).

Eric Bain Wasmund, global managing director at Eriez Flotation Division, says: "Almost all of the Tier 1 mining companies are now recognising the utility of our HydroFloat for floating coarser feed and producing a coarse feed in base metal applications."

Eriez Flotation Division also has a number of pilot plants testing this technology and – at the bottom of the pyramid – many lab-scale testing applications. Wasmund states: "The public will hear more about these endeavours in the near future."

Additionally, the company will soon have the first commercial application of its StackCell in base metals. Wasmund says: "The StackCell is a two-stage flotation unit featuring a tank within a tank architecture, which allows for much more efficient flotation."

Several major mining companies have conducted test work and engineering studies to examine the best place to insert the HydroFloat. Right now, the conclusion is that the best business case is for putting the HydroFloat on the tailing stream, where often more than 50% of the metal contained is in the coarse fraction.

"We also have mining companies looking at placing the HydroFloat right into the concentrator," notes Wasmund. "This placement provides even more benefits, but opportunities for this application on brownfield projects are rarer."

Eriez Flotation Division has re-designed its 3m StackCell for base-metal applications and is also

"Sustainability and making better use of water are also important trends in flotation"

completing beta testing of an intelligent SlamJet sparger called the IJet. Wasmund says: "The IJet offers numerous capabilities, including providing wireless real-time performance diagnostics."

Metso

Metso has found that demand for flotation equipment has been strong this past year, especially for mining applications. "Metso has seen the greatest activity in the Americas, Europe and Australia with an emphasis on lead times for flotation cells," remarks Howie. "The recently renewed RCS flotation cell has been the focus in discussions with our customers, due to the CAPEX and performance advantages of this technology."

In the last year, Metso has supplied RCS machines (conventional round cells), microcell columns and DR machines (conventional rectangular cells) to various mines. For example, McKay says: "When a large copper miner was preparing for both an optimisation project and expansion project, Metso presented the RCS as a solution."

This large copper miner saw improved performance with the installation and commissioning of Metso RCS for its optimisation project. Two RCS cells were installed on its two existing bulk cleaner lines and resulted in a global recovery increase from 80% to 84%.

Howie explains: "The concentrate from the new RCS cells is typically sent to final concentrate,

while the concentrate from the existing bulk cleaner (non-Metso) cells is sent to an additional stage of cleaning. Fabrication of the expansion project is underway with installation expected to be completed by the end of 2018."

According to McKay, many successful plants also utilise both froth cameras and advanced process control through a Metso OCS-4D ►



Metso's Microcel high recovery flotation columns are designed to increase product recovery and improve plant profitability

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► software based expert system. The optimising control strategy for all of these is based on the use of a technique called dynamic constraint control, which pushes flotation plants to drive for higher pulling rates to maximise mineral recovery within plant physical and metallurgical constraints.

"The extensibility and alignment of dynamic constraint control with plant KPIs [key performance indicators] makes it very attractive to Metso's clients," says McKay. "Typical results when applying this technique have been between 1-3% increase in mineral recovery."

In the last year, the RCS was selected for wide range of mineral applications, for both metallic and industrial minerals. "Some clients requested reducers drives instead of v-belt drives for improved maintenance, and Metso is flexible enough to meet customer specific requests," notes Howie. "Metso also supplied RCSHD (heavy duty) units to handle large volume coarse particle applications."

The microcell columns are selected for applications where fine particles and grade are important parameters of the flotation machine operation and success, while the DR cells are selected for coarse particle flotation and are advantageous for industrial mineral processing.

"Metso is committed to developing solutions for our customers based on their needs," says Howie. "We just recently modernised our froth vision system, VisioFroth."

"Currently, we are collaborating on several research and

development projects, which range from performance upgrades on the current technologies to the introduction of the next generation of flotation. More information on the new products and services will be announced in 2019."

Chemicals

Axis House

Axis House produces and supplies a range of collectors specifically for the flotation of metal oxides.

At First Quantum Minerals' Kansanshi copper mine in Zambia, the company provided collectors for improved kinetics and recovery, frothers for improve grade and depressants for reduced contaminants in concentrate. Also in Zambia, for First Quantum subsidiary Kalumbila Minerals' Sentinel copper mine, Axis House provided collectors for improved selectivity against pyrite and frothers for improved grade.

The company supplied Nevsun Resources' Bisha copper-zinc mine in Eritrea with collectors for improved recovery, and Metorex's Kinsenda copper mine in the Democratic Republic of the Congo (DRC) with collectors for improved recovery and selectivity and flocculants that produced cleaner process water that is recycled to the plant. Meanwhile, it provided frothers that reduced operating cost to Buenaventura subsidiary El Brocal in Peru.

Axis House's recent releases include TLQ2-DX, a selective collector towards chalcopyrite with little affinity for pyrite, and Revadep

Cu++, a dispersant effective for reduction of carbon and insols in concentrates.

Clariant Mining Solutions

Clariant Mining Solutions' flotation products are used around the globe in every continent and every type of flotation operation. "Clariant is continually developing new offerings to address the needs of the industry through our corporate initiative, Clariant Innovation Excellence," states Dopico. "As a result of this drive to develop the products of tomorrow, Clariant has introduced into the sulphide flotation market Hostafлот xanthate replacement products, which allow operations to discontinue the use of sodium isopropyl xanthate and potassium amyl xanthate."

Recently, a mine in South America was using potassium amyl xanthate in a copper gold flotation circuit, and Clariant's Hostafлот 7000 completely replaced the use of the xanthate collector while reducing collector usage.

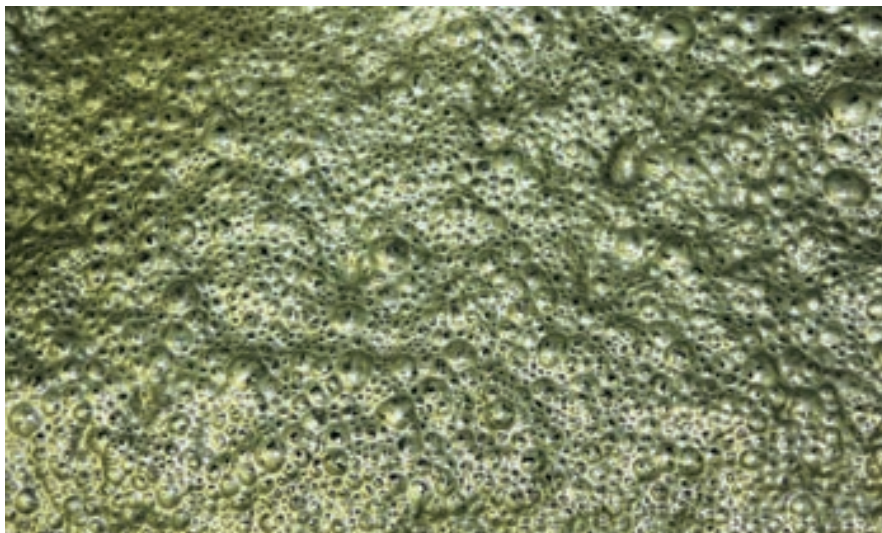
"The copper bearing minerals were predominantly bornite and chalcocite, with smaller quantities of chalcopyrite, and the gangue minerals included silicates, magnetite and carbonates," says Dopico. "Clariant's technical team developed the Hostafлот 7000 xanthate replacement collector and evaluated its performance in our metallurgical laboratories."

"Subsequently, the flotation results were verified at the customer's laboratory, and eventually the performance was demonstrated in full commercial trials, which proved that Hostafлот 7000 could replace the mine's previous collector package of potassium amyl xanthate and a secondary collector. In addition, Hostafлот 7000 allowed the mine to reduce their frother consumption by 25%."

In two other mines that were using sodium isopropyl xanthate in their copper and molybdenum flotation circuits, Clariant's Hostafлот 7257 was able to replace the xanthate collector that was being used either as primary or secondary collector, while also delivering the same copper and molybdenum recovery and grade that the operations were achieving previously.

"As in the case of the previously mentioned copper and gold mine, ore samples from the copper molybdenum mines were tested in ►

Clariant's flotation products are used around the globe in every continent and every type of flotation operation



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Could technology fundamentally disrupt mining as we know it?

According to various industry experts, technology could fundamentally disrupt current mining business and investment models if it manages to help the industry regenerate more efficiently and cost-effectively.

"We are just now seeing the advent of machine learning algorithms to sift through massive piles of data," explains George Adams, general manager, corporate and leader, and partner at iStock's Disrupting Initiative (with Goodbody). "Innovative technologies such as augmented reality and virtual reality are also changing the way we manage risks and develop mine plans. The discoveries that will be made as a result of the application of new technologies will directly flow benefits through to investors."

"Equally important, when one starts to dig into what are done - in other words applying technology to become better at what one does - the cost of what one produces typically goes down, which translates to increased bottom-line profits, and potentially more cash being returned to investors by way of dividends." (2) <http://bit.ly/2vONPf6>

Do you think that this transition will be seamless, and is your company ready for it?



Modern miners must regenerate, or fail

(Exclusive Future of Mining Channel presentation-Mining Disrupted)

Like Comment 29 12 11



Patricia Savage It already has just will continue to do so.

Like



Simon Ting Innovation are the lifeblood of any industry and its purity is undeniable

Like



Oliver Egan Mining has been mining in the same way it has for 40 years, just little advances. Let's see if the next 20 years, can we change it.

Like



Rebecca Durnell One important angle in this whole mining regeneration effort is social performance in dealing with local stakeholders. This cannot go to the back as an externality.

Like



Arthur Mawell It is not only better use of data that will change the future. New methods to access ore bodies (open-pit, underground and novel ore handling techniques are already available and being applied. The mining industry has traditionally been not aware when applying new technology solutions, due to perceived future consequences. This attitude is changing, new mines are being designed with new (sometimes expensive) technology. The message is "just make it work".

Like



Claude Mendelsohn My first career with iStock was with Patricia my long time colleague! That technology that disrupts mining business practices will continue in the future, will continue to do so. I disagree with Arthur's comments that "mining has traditionally been risk averse when applying new technology solutions." There are few industries who take risks than the mining industry... "a" chapters can be written on mining innovation and the risks associated with mining throughout its life cycle. Of course there is always room for the do more.

Like



Anita Straker We are "risk averse" because mines are often in remote areas and getting support takes time. However mining has been innovating for the past 6,000 years. If we were not for innovation we could have been mining to collapse.

Like



Bob Vincent The mining industry is slowly moving forward into the 21st Century and new technology is leading the revolution. It has to happen because the mining industry cannot survive as it exists now. New technology will make it possible for mining companies to extend the life of old mines by using them, using mining as the key to economically mining massive veins of precious metal, precious stones such as diamonds, and mining without the danger and the cost of using explosives. The new mining units (larger times has designed will operate remotely, silently, and without the need to bring tons of rock to the surface (and to restore small quantities of gold and silver) will be your solution. www.miningmagazine.com, to learn more.

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Lorraine Roberts Mining disrupted will also under discussion at the Future of Mining Americas conference in Denver from October 20-21. about, Jessica, Chief Digital Officer, Vale, Therese, Hameg, Vice President, Digital Innovation, Dundee Precious Metals and iStock MiningMag will debate key topics including operational competition between mining companies, future sources of competitive advantage, and the evolution of collaboration. Find out more at <http://americas.futureofmining.com/>

Like

Is your mining company ready for the next boom?

There is a new technology and resistance to change hanging in the air within mining, says George Hameg - uncertainty, however is not the next wave. The fault lies in value.

The mining companies that will prosper in the next cycle will be those that have defined from where they will derive value and what this implies for the prioritization of technology, capabilities, talent and portfolio. Will your company be one of them? <http://bit.ly/2vONPf6>



Waiting in the wind

There is a new technology and resistance to change hanging in the air within mining.

Like Comment 18 12 11



Richard Miles Why do we always have to consider the mining industry to be in a boom or a bust - the absurd reality by posing such questions forward.

Like



Timothy Te I agree Paul, the implied inevitability of painful cycles leads to deflation and excludes sources of capital that could be very good for the industry.

Like



Angela Kneagaw But, that's the reality of how companies react. So you've got to rethink, recognize that the industry could end in a longer time horizon. That would take CEO and for the investor market allowing that longer horizon, despite the pain of lower prices in, perhaps prepare for the "boom cycle" (which, let's face it - comes with lower prices and profits) by setting yourself up for the inevitable when times are good.

Like

► Clariant's metallurgical laboratories to demonstrate the performance of the Hostafлот 7257 xanthate replacement product against the xanthate incumbent," explains Dopico. "Following successful tests, the results were replicated first at the mines' metallurgical laboratories and eventually in full commercial trials.

"Both mines valued the improved sustainability of the Hostafлот 7257 xanthate replacement product, as it allowed them to reduce worker

exposure to xanthate in the preparation of xanthate solutions and in the handling of contaminated xanthate packaging, and ultimately it allowed the mines to reduce waste."

Under its Hostafлот brand of collectors, Clariant has introduced xanthate replacement products into the flotation market. These products allow operations that float sulphide minerals to replace xanthates, such as potassium amyl xanthate and sodium isopropyl xanthate, with Hostafлот collectors that are

delivered in bulk in liquid form, eliminating the need to dispose of contaminated packaging that results from the use of xanthates.

"The Hostafлот liquid xanthate replacement products also increase safety because, unlike xanthates, they are not flammable," says Dopico. "Furthermore, Clariant's Hostafлот xanthate replacement products also eliminate the employee exposure associated with unloading bags of xanthates daily to make solutions, as well as the

ArrMaz case study

Mining chemicals producer ArrMaz recently helped a spodumene producer to exceed grade and recovery targets while reducing collector consumption by 68%.

The company's client, a spodumene mineral processor, opened a mine with the intention of producing a battery-grade spodumene product. Its deposit presents various metallurgical challenges related to mica- and iron-containing silicate minerals; the mineralogy of the deposit is 10-20% spodumene with a high percentage of quartz and iron silicates, mica, amphibole and more.

In order to produce a battery-grade product, the spodumene concentrate had to be upgraded from 0.8-1.2% lithium oxide (Li_2O) to >6.0% Li_2O . The client's processing facility was having difficulties achieving concentrate levels above 4.5% Li_2O , as well as making the recovery and production targets projected in the mine pre-feasibility study.

As the plant started up, several processing challenges reduced recovery versus targets and hindered processing steps:

- The operation had difficulty meeting production goals;

- The mine started up on a commodity-type collector;
- Reagent consumption was high; and
- Grade targets were not consistently being met.

A technical partnership was established between ArrMaz and the mineral processor focused on two key areas: collector formulation customised to its unique feed, water and process; and process optimisation.

ArrMaz manufactures custom surfactants designed to improve the selectivity and strength of spodumene flotation. Laboratory floats on the processor's feed samples were conducted in ArrMaz's metallurgical lab in Mulberry, Florida, US to pre-screen the chemistry and formulary types to meet grade and recovery requirements.

A custom-formulated surfactant-enhanced reagent, CustoFloat 7080, was found to be the most effective. Selectivity and froth structure were custom designed to reject iron-containing contaminants in order to satisfy grade requirements.

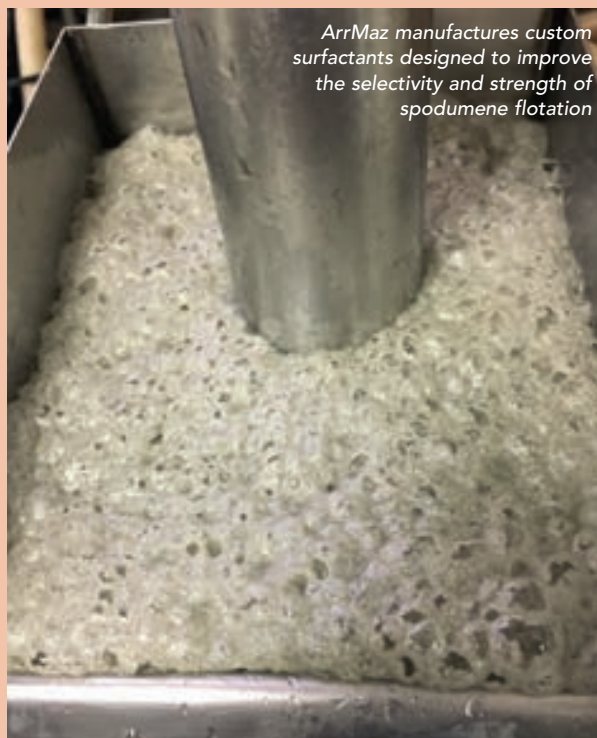
Arrangements were then made to conduct laboratory tests at the processor's site to verify the initial findings. CustoFloat 7080 was proven to handle the range of varying feed and operating conditions encountered in the plant. CustoFloat 7080 plant testing was conducted versus the commodity collectors previously used and the new collector was found to successfully meet the grade target of 6%.

A team comprising members from each company was formed and a brainstorming session on process troubleshooting was conducted. Working with the client, ArrMaz laboratory and process consultants examined the company's process from beginning to end, and were able to adjust feed processing and mineral conditioning parameters to maximise plant and reagent performance.

Over the 3-4 month testing period, CustoFloat 7080 was able to consistently make grade targets, as well as provide acceptable recovery and production tonnes. The following key results were achieved:

- Flotation selectivity was improved as the ratio of Li to Fe increased significantly;
- A stepwise process was developed to tweak operating parameters, and CustoFloat 7080 formulary was fine-tuned to better match the collector and feed;
- Collector consumption was reduced by 68%;
- Collector ease-of-handling and make-down efficiency was improved; and
- During the course of this development effort, the performance criteria for the site was met, putting the plant back on track with the expectations of the prefeasibility study.

ArrMaz states that the supplier-client partnership continues today, now focused on further increasing recovery with new collector development. Work on new collector formulas show further improvement in lithium flotation selectivity over iron contamination.



ArrMaz manufactures custom surfactants designed to improve the selectivity and strength of spodumene flotation

waste associated with xanthate solutions that have degraded and must be discarded."

Flottec

Recently, Flottec's new operation in Chile called Flottec Chile has been working on a large copper-molybdenum operation in the northern part of the country. Flottec was asked by the mining company to work on improving its recoveries and to lower its costs.

Cappuccitti comments: "We performed an audit of their operations and discovered that both their reagent scheme and automated process control strategy need improvements. Taking a holistic approach, the reagent costs were lowered by over US\$3 million and their operating strategy was improved that allowed higher throughputs and higher recovery in their circuit. The operating strategy was changed based on new hydrodynamic understanding of flotation circuit mass removal strategies.

"These strategies were implemented, resulting in an

immediate improvement in the grade of the rougher circuit, allowing less mass going to the cleaner and thus improving overall copper recovery in the plant at higher final grades."

The change in reagents came as a result of the study of the company's very complicated collector scheme. "Their collectors were various mixtures of collector, frother and hydrocarbon oils," says Cappuccitti. "This mixture tried to give them everything they might need in one product. But in the end, it reduced the flexibility to independently add collector for molybdenum, collector for copper and frother. Every time you modified the addition of collector, you added everything else as well; so you had conditions where you had too little copper collector and too much frother and couldn't add any more collector due to the overfrothing."

By decoupling the collectors and frothers, Flottec Chile was able to reduce collector consumption from 25g/t to 5g/t and still improve the operation and lower costs tremendously.

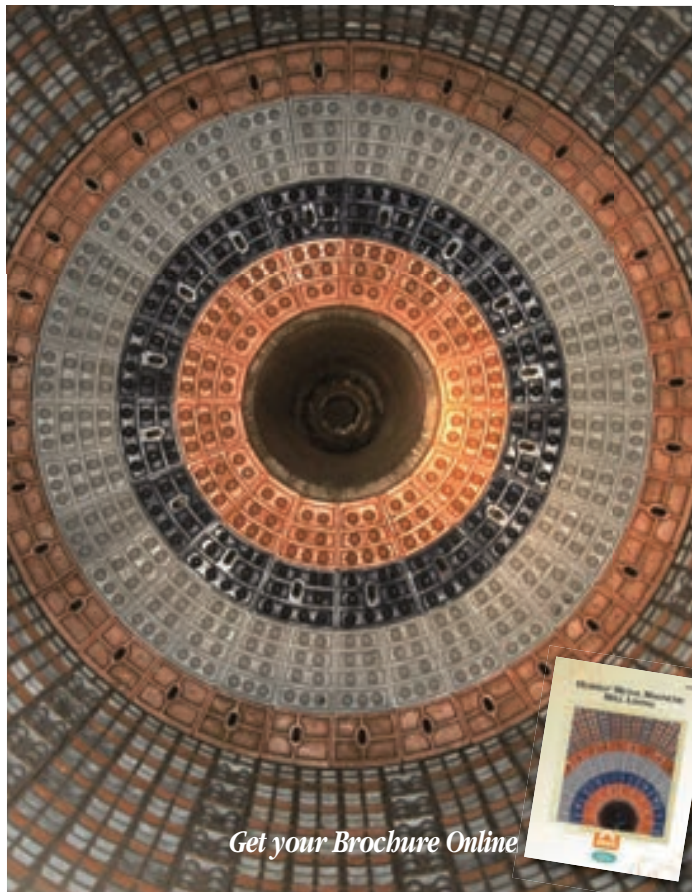
Cappuccitti notes: "We have also gone on to the next stage where we are working on actually changing the collector to a product that is more selective against pyrite to be able to reduce the SMBS [sodium metabisulphite] used in the plant and lower recirculating loads of pyrite in the cleaning circuit. The plant uses seawater, so this complicates the addition of lime as it will not raise the pH and control pyrite which is a more standard approach."

Flottec has also been working very hard on understanding the use of oils in flotation. "Our research has shown that we can deliberately target coarse and fine naturally floating minerals with various different compositions of oils and various viscosities," says Cappuccitti. "Also, we can tailor the chemistry for better toxicological properties based on our data if the customer wants this. Our full product line will be launched in late 2018."

Nalco Water

Nalco Water supplies a diverse range of flotation reagents that

"Mines are installing larger and larger flotation cells and more complex circuits"



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► are in use globally in applications including coal flotation, metal sulphide flotation and phosphate flotation.

"In North and South America, we have been approaching the market with customised FrothPro frother blends where we create a bespoke blend on-site during trials to cater for specific site needs," explains Zwaneveld. "There has been enthusiasm in the American copper market where we focus on improving coarse particle recovery for grinding limited sites. Beyond improving flotation performance, improving recovery and allowing us to manage froth persistence, we

have been able to change the frother as the orebodies change."

He notes that the coal industry has been under pressure to reduce costs while still meeting the rising demand for metallurgical coal in China. Zwaneveld says: "Recent successes have included the sale of CoalEx, a new high performance and environmentally friendly collector that is helping mines produce millions of dollars per month more coal while reducing costs."

Additionally, there are several coal mines in Australia that are using Nalflote frothers combined with the FloteFeed application technologies producing yield increases of 2-3% while reducing total cost of

operations. Zwaneveld states: "One such metallurgical coal site increased their net revenue by US\$8.3 million per year."

Zwaneveld says that mines are choosing Nalco Water's FrothPro blends, because once at site the company is able to blend the best product for a particular orebody and mine site and improve recovery by capturing ore particles that may otherwise be lost.

Nalco Water has released several new product and technology innovations in the last year. FrothPro is a range of formulated frothers that improve mineral recovery and performance in metal sulphide and phosphate applications by creating stronger and more robust bubbles that are better able to capture coarse particles.

In addition, Collect-Ore is a new range of formulated metal sulphide collectors that are designed to deliver improved recovery and pyrite rejection over conventional flotation collectors. Zwaneveld comments: "The formulations are particularly exciting by shifting the grade-recovery curve to the right while often reducing dose and costs. This, combined with Nalco's extensive on-site service model, means that operations are always at their best."

Finally, FloteFeed is a flotation reagent dosing system that maximises reagent dispersion to increase kinetics. ♥

Nalco Water supplies a diverse range of flotation reagents that are used in coal flotation, metal sulphide flotation and phosphate flotation
Photo: Nalco



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Annual subscription (Mining Magazine digital)
UK £199.00 Europe €278.60
US/rest of world \$308.45 Australia \$398.00

Mining Magazine USPS 005-829 is published 10 times each year with combined issues in Jan/Feb and Jul/Aug – by Aspermont Media, WeWork Aldgate Tower, 2 Leman Street, London E1 8FA UK. Printed by Stephens & George Magazines, Merthyr Tydfil, UK

The 2018 US annual subscription price is US\$308.45. Airfreight and mailing in the US by Agent named Air Business, c/o Worldnet Shipping USA Inc, 149-35 177th Street, Jamaica, New York NY11434 Periodicals postage paid at Jamaica NY 11431

US Postmaster: send address changes to Mining Magazine, Air Business Ltd, c/o Worldnet Shipping USA Inc, 149-35 177th Street, Jamaica, New York NY11434

Subscription records are maintained at Aspermont Media Ltd, 21 Southampton Row, London, WC1B 5HA, United Kingdom

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Aspermont Media
Information for Industry

© Aspermont Media 2018 ISSN 0308-6631
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