A state of flux

The application of new, innovative chemical formulations are helping miners lower their costs as well as reduce their environmental impact, Dan Gleeson reports

Designed to support metallurgists in optimising recovery in continuous leaching, Orica's LeachIT simulation software allows customers to visualise and predict gold leaching outcomes based on a mine's unique requirements

The COVID-19 pandemic has failed to push the mining sector's environmentally focused chemical use agenda off course, with all reagents, depressants, extractants and collectors being heavily scrutinised for their risk to the environment as well as their potential effectiveness in the process plant.

This continues to be best displayed in the cyanide space, where manufacturers and users of the lixiviant are re-evaluating its place in the industry.

Two recent news items exemplify this better than most.

Cyanide conundrum

In March, the **Chemours Company,** a global chemistry company, announced the initiation of a strategic review to assess the potential sale of its Mining Solutions business, a part of the Chemours Chemical Solutions segment.

The process, intended to drive shareholder value and portfolio focus, could see one of the largest North America-based producers of solid sodium cyanide come off Chemours' books.

Ed Sparks, Chemours Titanium Technologies and Chemical Solutions President, said recent investments in production capability and infrastructure at the company's Memphis plant – the largest solid sodium cyanide plant in the world – along with supply chain optimisation efforts to reduce costs, would enable Mining Solutions to "maximise growth and margin expansion, further increasing the value of this highly successful business".

He added: "The Mining Solutions business remains committed to addressing the ever-changing needs of the precious metals mining industry, throughout and following this strategic review."

In the same month as Chemours came out with this review, Cyanco, a leading producer of sodium cyanide for precious metal extraction worldwide, announced it had formed a strategic partnership with Cycladex Ltd, the developer of a newly patented cyanide-free process to rapidly recover gold and silver.

The companies established a funded joint technology development program and a revenue sharing agreement on collaborative projects that, they said, would benefit both.

Through the partnership, Cyanco says it can expand its offering aimed at the safe and efficient recovery of precious metals from ore. Cycladex, in turn, benefits from Cyanco's established infrastructure and customer base, enabling it to, the company says, grow its presence in the mining industry.

Cycladex uses a novel, patented chemical process to recover gold and silver that does not use cyanide, reduces operating and capital costs, reduces gold recovery time scales, uses around 50% less water and helps gold miners avoid land contamination, it says.

It sees gold leached from the ore using a bromide-based lixiviant that forms a tetrabromoaurate complex with gold. A solution of corn starch derived -cyclodextrin is added to the leachate and, upon addition of the -cyclodextrin, the lock-and-key crystal structure forms spontaneously and precipitates. The gold is then released from the crystalline precipitate at high temperature to yield solid gold metal, the company explained.

Developed by Nobel Prize winner, Sir Fraser Stoddart, Director of the Center for the Chemistry of Integrated Systems at Northwestern University, this process has been proven for mining operations too remote to receive sodium cyanide, or whose infrastructures or ore characteristics may require a different mineral extraction process, Cycladex said. This

has seen the technology work on ores at more than 30 mines worldwide.

Recently, the company, together with BC Mining of Baja Mexico, completed its first demonstration unit which has the capacity to process 2-4 t/d of gold ore. And, together with Triple 7 Mining, a gold company in Arizona, USA, it completed scale-up gold ore leaching trials running more than 20 batches at pilot scale.

Cyanco President and CEO, Michael Lefenfeld, said: "Cyanco is continually evaluating new technologies with the potential to increase mineral yields for our customers. Each mine is different, with a range of ore characteristics, processing variables and unique environmental factors.

"Through partnering with Cycladex, we believe we will be able to serve more mining customers – both large and small – by addressing a broader spectrum of mining needs, while continuing to focus on improving process efficiency and lowering operating costs."

Roger Pettman, Executive Chairman of Cycladex, added: "I am delighted to have entered into this partnership with Cyanco. Their outstanding reputation in the industry, technical expertise and global distribution network will allow us to expand our technology commercialisation efforts and help us realise our full growth potential."

He added: "We see many opportunities where the Cycladex technology fits nicely in a product portfolio alongside sodium cyanide."

Switzerland-based **Cyanoguard AG** is all too aware of the changing patterns of precious metal producers when it comes to the use of cyanide. Indeed, it is capitalising on this trend.

The company has come up with a novel way of ensuring more accurate dosing of cyanide for cyanidation with a process that is now established with 18 clients across the globe.

It has devised a reliable, user friendly and intelligent real-time cyanide monitoring and optimisation solution that minimises toxic reagent usage and greenhouse gas emissions, while improving precious metal recoveries for gold mines, it said.

It does this by combining chemical sensing technology with a cloud-based data visualisation and analysis solution for "holistic monitoring and optimisation". Its patented single-use test cartridge changes in colour instantaneously based on cyanide concentration in the sample solution, delivering accurate results in less than 30 seconds anywhere on the spot, without any lab equipment or training, according to the company.

CyanoGuard's Head of Mining Solutions Sales, Margarita Zvezda, says the company's technology removes the need to overdose cyanide, which has a direct impact on lixiviant costs as well as environmental impacts.

CyanoGuard's cyanide dosing solution combines chemical sensing technology with a cloud-based data visualisation and analysis solution for "holistic monitoring and optimisation"

"Adding the right amount of cyanide is critical in gold production because it directly impacts recovery ratios," she told ***IM***.

This is a challenging task as the cyanide control methods prevalent in the gold mining industry – in particular, those based on silver nitrate titration – are highly unreliable, she said. As a result, mines tend to overdose cyanide to be on the safe side.

"This turns out to be an expensive choice though," Zvezda said.

CyanoGuard's solution addresses this problem by offering much more accurate and reliable cyanide measurement technology, which has almost no interferences and is digital, thus minimising any potential human error.

"It is also a very fast method, allowing management decisions related to cyanide control to be taken very promptly," Zvezda said.

This same reliability issue with cyanide control methods can also see companies under-deliver cyanide during the cyanidation process – directly impacting recoveries.

"With CyanoGuard's solution, such situations can be identified and resolved within minutes, thus helping to achieve better gold recovery ratios," Zvezda said.

The savings on the solution go beyond simply cyanide use.

"Excessive cyanide usage implies higher water consumption as well as detox reagent costs," Zvezda explained. "Not only does CyanoGuard's technology automatically address both of those cost categories, but it also proves efficient in cutting the less obvious expenses: in particular, those related to downtime." The latter point is particularly true as CyanoGuard's devices require no maintenance or calibration.

With CyanoGuard's platform, gold mining companies can reduce cyanide consumption during the gold mining process by 15-20% through improved process control and lower detoxification costs, while detox reagent savings of 20% can be achieved along with improved recovery rates, the company claims.

The CyanoGuard solution is 'plug and play' and very easy and intuitive to use, Zvezda added.

"It does not require any changes to the production process, or any special preparation/training from the team who uses it," she said. "You can implement it in just a couple of days and start seeing a positive impact on costs and operational efficiency almost immediately."

Australia-based Orica has also devised a cyanide measuring system to optimise the chemical's use.

With the mining industry primarily relying on lab experiments and plant trials to optimise gold leaching processes, Orica said it felt the need to provide a different option with its LeachIT™ solution.

Designed to support metallurgists in optimising recovery in continuous leaching, LeachIT simulation software allows customers to visualise and predict gold leaching outcomes based on a mine's unique requirements. In doing so, it does away with the time consuming and uncharacteristic results that can come with these lab and plant tests, and enables customers to see just how the given process will respond to changes.

It does this by using historical data from a myriad of sources to form the model. Once the model is set up, it takes very little effort and time to perform multivariable analysis, according to Orica.

Aimed at enabling best practice leaching, LeachIT simulates changes to the process and presents the impact on tails grade. The software harnesses this information not only to calculate but also visualise gold recovery and cyanide consumption.

Recent updates to LeachIT are aimed at improving customers' ability to process gold more efficiently and reduce overall cyanide costs

and consumption.

With the latest upgrades, LeachIT is now able to ingest data from sources such as laboratory experiments and pilot plant trials, according to Orica's Paul Martin, Global Cyanide Customer Solutions Manager, and Greg Zwolak, Senior Metallurgist.

"By enabling data inputs beyond that of plant data, the overall model fit can be vastly improved," Martin and Zwolak agreed.

LeachIT can also now output optimum cyanide to oxygen ratios for each tank, as well as predict the impact of the changes on concentration of Weak Acid Dissociable cyanide in plant tails, the pair said. This allows cyanide detox costs to be accurately predicted, resulting in more precise knowledge of the overall costs and benefits of any changes.

The final enhancement to LeachIT is its ability to model systems that have a number of ore types processed at the same time. This allows for optimisation of process conditions for various ore mixtures that require different optimum process conditions.

Martin and Zwolak concluded: "With customers already taking advantage of the improvements, Orica believes customers can substantially improve profit by increasing the percentage of gold recovered from the ore and reducing operating expenditure. This is all achieved by reducing the time, cost and accuracy of the predictions."

Chemical challenges

Beyond cyanide use, there are a plethora of chemical companies looking to solve industry challenges, with one of the frontrunners in this sector-wide problem-solving being Belgium-based **Solvay**.

The company has made a living off providing clean chemicals that improve recoveries and environmental impact, while reducing impurities.

It has recently been advancing the commercialisation of its next-generation sodium hydrosulphide replacement technology, the AERO® NR 7361 depressant, which has a role to play in today's and tomorrow's copper operations.

It explained: "Copper mines contain valuable by-products within their ore that contribute to a mine's overall economic performance. Ores with both copper and molybdenum need to be concentrated together into a bulk flotation concentrate before being separated from one another prior to further processing."

Molybdenum is commonly separated from copper using sodium hydrosulphide (NaSH), yet mining operations often dislike the use of NaSH due to the smell, risk of exposure to highly toxic hydrogen sulphide gas, high treatment cost, performance deficiencies when treating difficult ores and logistical challenges in handling large volumes, according to Solvay.

Molybdenum flotation circuit using the AERO NR 7361 depressant

Eammon Guitard, Mineral Processing Marketing Manager at Solvay, said: "The mining industry is continually looking to reduce hazards in the workplace and minimise potential exposures for employees. Sustainability is clearly a driver for major mining companies as they look to reduce risk around hazardous chemicals."

Solvay previously introduced its AERO 7260 HFP depressant technology as a safer and sustainable alternative to NaSH. While well received and in commercial use globally, the depressant was only able to replace up to 60% of the NaSH, the company admitted.

The industry wanted more, according to Esau Arinaitwe, Mineral Processing Innovation Director at Solvay.

"Our customers asked us to push this even further and set the goal to replace 100% of the NaSH used," Arinaitwe said. "Given the high demand for our partial NaSH replacement AERO 7260 HFP depressant technology, we knew the market was looking for alternatives, so we continued working to eradicate NaSH."

Solvay's latest innovation, AERO NR 7361, replaces 70-100% of the NaSH used in copper-molybdenum separation and provides a wider operating window than the previous generation product, according to the company.

"These depressants are chemically stable, highly effective sulphide reagents, making them safer, practical and sustainable alternatives for copper-molybdenum separation because they substantially reduce and/or completely eliminate NaSH consumption," Solvay said.

The AERO NR 7361 depressant is now in commercial use at a large copper operation in North America, which achieved 100% NaSH replacement at an overall consumption of 1.5 kg/t of molybdenum plant feed compared with the previous 11.5 kg/t NaSH consumption. This provided estimated operating cost savings of around $3 million/y due to lower dosage requirements when using AERO NR-7361, Solvay said.

On top of that, metallurgical results indicated AERO NR 7361 provided advantages in terms of better copper and iron depression, resulting in higher molybdenum concentrate grades, more efficient removal of lead impurities from the final molybdenum concentrate and, overall, stable molybdenum plant operation.

The technology is being rolled out globally with two additional operations in advanced trial phases and several laboratory evaluations progressing and trials pending, Solvay said.

Alfredo Santana, North American Technical Director, concluded: "Our customers' reception has been very positive. The product's performance has met customers' expectations and operations have seen reduced treatment costs and improvement to molybdenum concentrate grades with no significant downstream impacts."

Nitrating conditions in Latin America

Depleting grades and higher consumer demand from electric vehicle manufacturers and the like are not the only challenges copper mines in Latin America face, with solvent extraction operations also battling with the added problem of nitration.

Most copper solvent extraction operations in Latin America are now working with Solvay to overcome this and many other issues, according to the chemical company.

Rodrigo Zambra, Regional Sales Director LATAM at Solvay, explained the challenge: "Ores across Latin America have a higher concentration of nitrates than elsewhere in the world. Nitrates degrade metal extractants. Mines, therefore, need a nitrate-resistant product for their solvent

extraction operations but many of the options that have been conventionally employed have failed to adequately address the situation."

Changes in ore feeds, due to mining new ore deposits or toll treating ore, may introduce nitrate salts to solvent extraction operations that previously had not faced this phenomenon, according to Solvay. The presence of nitrate in acid solutions can lead to the formation of nitronium ions, which react with oxime, resulting in nitro-oxime. The nitrated oxime binds with copper to form a highly stable complex, leading to higher viscosity and related physical problems. In addition, this copper complex cannot be stripped under normal plant conditions, generating a recirculation of copper in the organic phase (residual copper) that decreases the recovery and, thereby, the transfer of copper.

To enable mining operations to overcome nitrating conditions, Solvay has introduced ACORGA® NR series copper solvent extractants to help mines protect against degradation of their solvent extractant. This, the company says, reduces extractant replacement costs and improves operational reliability.

Solvay's offer extends beyond nitration-resistant reagents, with the company's Metal Extraction group having developed a proprietary TAP (Tert-Amyl-Phenol) test methodology. This is a unique indicator of nitration aggressiveness, Solvay said.

The company also supports customers through advanced gas chromatography (GC) and liquid chromatography (LC) analysis, both of which are critical to assessing initial nitration conditions across customer sites in Latin America and evaluating the benefits of the ACORGA NR in those conditions.

Last year, a large copper solvent extraction operation in northern Chile faced nitration issues related to its oxime-adopted ACORGA NR at commercial scale. The problem occurred after a year of industrial trials in which the drop of oxime nitration was confirmed through GC and LC analysis. Solvay designed and performed more than 64 TAP tests in the lab, followed by two months of data statistical analysis to generate a 3D diagram, plotting the pregnant leach solution (PLS) nitration potential as a function of nitrate concentration and acid concentration. This tool enabled the operation to predict the nitrate conditions of the PLS entering its solvent extraction plant and adjust parameters to minimise the risk of nitration of the organic phase, it said.

Another plant in the region recently switched to ACORGA NR following two pilot plants run side-by-side at its site and at Solvay. The operation had been experiencing highly aggressive nitration conditions resulting in deficiencies in the solvent extraction process. This included higher residual copper, higher viscosity, lower production and extremely high extractant consumption. Although the operation was using a nitration-resistant extractant formulation, the test work demonstrated an imbalance between the amount of protector present in the organic phase and speed of formation of nitronium ions. This resulted in a fast consumption of the protector and, therefore, an increased extractant consumption to replenish the protector and maintain production targets.

The two pilots also showed that ACORGA NR, which contains a different protector than the incumbent formulation, is more resilient and can significantly reduce the nitration potential.

Switching to ACORGA NR has saved the operation well over $1 million/y in reduced extractant consumption, in addition to maintaining a stable solvent extraction plant and achieving copper transfer targets, Solvay said.

To facilitate the conversion to ACORGA NR by operations running other formulations when they encounter nitration issues, Solvay has developed custom "booster" formulations to ensure a plant reaches the appropriate concentration of protector in its organic phase at a speed much faster than standard make-up replacement.

Such boosters have been successfully used at numerous plants throughout Latin America that, after a few months, were running fully on ACORGA NR, Solvay said.

ACORGA NR series nitration-resistant reagents also have the same tailored metallurgical advantages when compared with unmodified reagents, including a reagent strength matched to the PLS conditions, improved selectivity and enhanced copper transfer, according to the company.

Heavy metal removal

To protect the safety of food supply while feeding a growing population and minimising environmental impacts caused by agricultural runoffs, regulatory limits on harmful heavy metals such as cadmium, arsenic and lead in fertilisers and animal feed products are rightly becoming more stringent.

Against this evolving backdrop, Solvay and its ACCO-PHOS® technology are helping the two sectors.

ACCO-PHOS 800 series reagents are, the company says, a unique, bolt-on chemical technology to enable the removal and/or reduction of heavy metals, especially cadmium and arsenic, from phosphoric acid by precipitation and appropriate separation systems

Compared with other technologies to remove heavy metals from phosphoric acid – such as solvent extraction, ion exchange, the use of adsorbents and membrane technology – ACCO-PHOS provides an easy-to-apply and highly effective solution requiring only minimal investment in equipment, Solvay claimed. It also comes with a viable treatment cost.

This phosphorus-based technology binds with heavy metal complexes, enabling removal with gypsum. ACCO-PHOS also has a low toxicity profile and generates minimal hydrogen sulphide in most phosacid production conditions, which can be safely managed with appropriate safety measures during application. The reagent can be added directly into existing production lines with a single pump and may remove other metal ions such as mercury and copper, if present.

In one case, a major fertiliser producer was unable to meet pending EU regulations regarding cadmium content in its finished fertiliser product. By using ACCO-PHOS, the customer lowered the cadmium content of its strong phosphoric acid from 30 parts per million (ppm) to 10 ppm, allowing them to meet the impending cadmium specifications.

In another case, an animal feed producer needed to reduce cadmium levels to meet specifications for a key product. Working with Solvay's technical application experts, the customer was able to reach economical dosages to reduce cadmium levels from 36 ppm to 6 ppm.

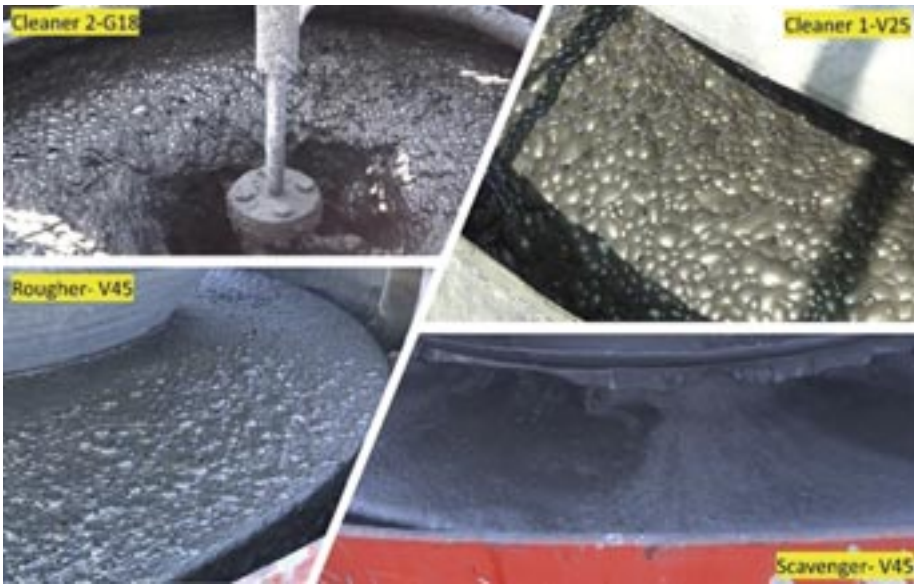
"ACCO-PHOS technology not only enables phosacid producers to meet regulatory requirements but helps them earn a competitive edge from a sustainability perspective," Solvay said.

For example, the EU is launching a "Green Label" initiative to allow fertiliser suppliers with low levels of cadmium (lower than 20 mg/kg P_2O_5) to label their products with a green label, the company explained. This special designation could enable suppliers to maintain or expand their customer base, positioning their organisations as early adopters of more sustainable agricultural production practices.

Selective chemistry, optimised physics

Having perfected its Imhoflot™ pneumatic flotation technology over the past 25 years, **Maelgwyn** is now looking to match reagents with the specific conditions of high-energy pneumatic cells as part of a research collaboration with South Africa-based chemical solutions provider **Axis House**.

In the quarter century since Imhoflot was introduced to the mining industry, it has evolved with multiple flotation cell designs for different applications, including vertically fed (V-Cell), tangentially fed (G-Cell), hybrid (H-Cell) and VC-



Froth properties of different Imhoflot flotation duties at the Andina copper tailings plant, Codelco Chile – chalcopyrite -20 µm

Cell as the latest design for coarse particles. This has led to over 180 installations in operations such as coal, potash, kaolin, magnesite, copper, gold, platinum group metals, copper-molybdenum, lead-zinc and reverse flotation of silica.

The unique selling point of the Imhoflot system, the company says, is the superior grade-recovery curve and the increased range of mineral particle sizes that can be recovered (both ultrafine (-20 µm) and coarse (-250+106 um)). This is achieved through high energy dissipation for the bubble-particle attachment and superior froth draining, which reduces gangue entrainment.

Maelgwyn says the research collaboration with Axis House will combine the selective chemistry of Axis House reagents with the optimised physics of Maelgwyn's Imhoflot system. With little industry research carried out into matching reagents with the specific conditions of high-energy pneumatic cells, the two think this area is ripe for further investigation.

The Imhoflot aerator is a fine bubble generator that has secondary benefits when it comes to improving the performance of flotation reagents, Maelgwyn says.

"For example, high turbulence in the aerator cleans the surfaces of minerals of both oxidation layers and adhered slimes," it said. "This increases reagent selectivity and reduces the dosing required."

Maelgwyn's work in the European Union's Horizon 2020 FineFuture project has pushed forward its competitive edge in ultrafine mineral flotation with base metal recoveries down to only a few microns, while maintaining the grade-recovery curve.

Maelgwyn's Imhoflot G-cell is optimised for ultrafine mineral recovery and is widely acknowledged to have several advantages over mechanical and column flotation associated with an increased recovery of fine particles, fast kinetics, high reliability, smaller plant footprint (capital expense savings) and a lower unit price than competitors.

The Imhoflot system also has a positive effect on the application of flotation reagents.

The concentrate froth from an Imhoflot cell looks different to the froth from a conventional mechanical cell. While this can take some adaption from the plant operations team when considering dosing, it does bring with it additional flotation performance, according to the company.

"The finer air bubbles generated in the pulp provide significantly higher bubble surface area per volume of air, resulting in higher bubble loading capacity with which to carry minerals from the pulp to the froth, thus maximising recovery of the collected particles for a given air volume," Maelgwyn said.

The Imhoflot cell also only requires a very short residence time due to increased bubble-particle attachment kinetics and superior froth draining. This minimises the depth of froth required to achieve the needed grade, meaning the operational froth depth is shallower than a mechanical cell requires.

The "tight froth" reduces the "plateau border" where the froth projects over the launder, which results in lower water recovery and carry-over of entrained gangue, according to Maelgwyn. This entrained water carriage of gangue is a significant factor to consider when floating fine particles.

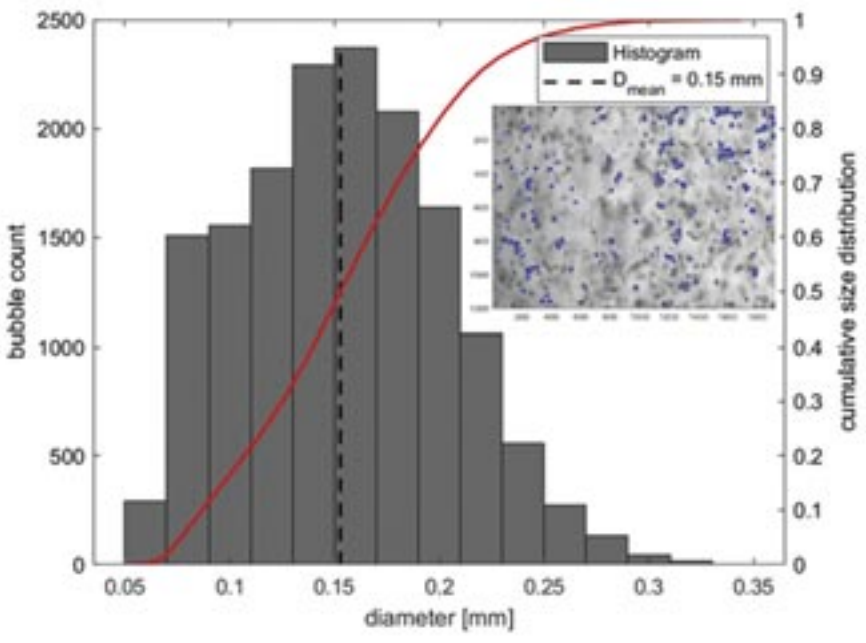
The quick draining and improved concentrate froth-flowing characteristics mean froth washing and launder water is rarely needed with the Imhoflot. This reduced water content of the fine concentrate cuts capital requirements for downstream solid-liquid separation, while reducing the requirement for de-frothing agents to prevent losses in concentrate thickeners.

Bubble size distribution

Maelgwyn's Imhoflot aerator design is based on the three industry-accepted mechanisms for bubble break-up:

- Rayleigh-Plateau instability of bubbles in shear flow;
- Impact of liquid accelerated flow inertia according to the Kolmogorov-Hinze approach; and
- Richtmyer-Meshkov instability of bubbles under high acceleration.

The patented design generates a spectrum of



A typical bubble size distribution generated by an Imhoflot reactor for the FineFuture project

fine bubble size, resulting in a very high bubble surface area per slurry volume and, thus, high mineral carrying capacities, Maelgwyn said.

The high-intensity environment not only produces very fine bubbles, but, most importantly, creates an intensely turbulent environment to enhance bubble-particle collision frequency and efficiency of the attachment interactions.

"This gives the reagent-conditioned mineral surface more opportunity to attach to the bubble or for surface nucleation to occur, and hence lower reagent dosing may be required for the same flotation effect," Maelgwyn said.

Imhoflot bubble-particle collision occurs within a high-shear zone where the bubbles are still "young" and not yet "contaminated" with adhered fine gangue minerals, the company explained. This improves the selectivity of reagents as the "active mineral surface" is unhindered and reduces the entrainment of fine gangue particles – both of which provide a higher-grade froth concentrate by increasing gangue rejection.

Due to the higher energy conditions used in the Imhoflot compared with other pneumatic cells, there is a high degree of dissolved gas molecules that nucleate to form nano-bubbles in both the gas-saturated pulp and at ultrafine mineral surfaces. This means both historic pathways for bubble-particle attachment are used within the Imhoflot, which benefits the flotation of ultrafine mineral particles.

Particle surface cleaning and reagent optimisation

Mineral flotation is a surface-chemistry reaction where reagents interact with the exposed surface of minerals. Therefore, ensuring a clean mineral surface, thinning the film boundary layers and breaking up any surface-adhered mineral phases are key requirements for the selective adsorption of flotation reagents.

The Imhoflot aerator focuses the energy release from the pulp into high-shear zones to generate high-speed turbulent eddies to polish the surface of the particles, removing the boundary film, oxidised minerals and slime coatings from the surface. This optimised reaction environment means lower doses of more selective reagents can be used to achieve superior flotation performance, according to the company.

It is this opportunity to use the higher performance reagents from Axis House at lower dosages that Maelgwyn hopes will unlock economic and environmental benefits for their respective clients.

The Imhoflot high shear environment disperses reagents into a turbulent zone to aid homogeneous dispersion, decreasing the time and dosing required to condition the entire pulp volume. This leads to operating cost savings and a smaller plant, Maelgywn says.

"The nucleation of nano-bubbles in the pulp and at the mineral surface enhances the bubble-particle attachment physics by lowering the interfacial free energy," Maelgwyn explained. "In effect, the nucleating bubbles act as a 'secondary collector', reducing the dosage of flotation reagent required."

Maelgwyn says it has found evidence that, in some flotation systems, the small bubbles act as carriers of the collector to the mineral surface from the pulp, which further increases the kinetics of flotation.

Fine recoveries

The Imhoflot G-cell is applicable for a range of particle sizes from ultra-fine (-20 µm) to intermediate-sized particles (50 µm).

The G-cell uses a "unique" dynamic centrifugal motion to promote gangue disengagement from mineral-bubble agglomerates within the pulp before gently spinning the concentrate froth to reduce gangue entrainment by both keeping the pulp-froth interface turbulence low and allowing gangue entrained in froth bubble interface water to drain away from the central concentrate launder by centrifugal force.

"It is this combination of factors which, when combined with a selective reagent scheme from a team such as Axis House, allow the G-cell to achieve superior concentrate grades," Maelgwyn claimed. "The G-cell often finds application in challenging cleaning duties or recovery of ultra-fine particles (down to 5 µm) where columns are struggling to achieve the recovery required."

Imhoflot cells can be supplied in modular forms to achieve specific test work tasks before installation of a full-sized cell or combined to provide a cost-efficient retrofit to existing plants.

For instance, the application of a three-stage G-Cell at a nickel plant in Europe demonstrated Imhoflot's ability to recover an additional 30% of nickel from the final tailings, predominantly in the -11 µm size fraction.

At another operation – this time zinc – a two-stage Imhoflot G-Cell plant was used to avoid losing metal in the -7 µm mineral particle category. In this operation, the G-cell recovered an additional 20% of the zinc from the final cleaner tailings.

Imhoflot is currently being trailed at one of the biggest gold concentrators in the CIS region where the existing conventional cells were not achieving the desired grade-recovery profile with the main gold losses reported to be in the fine (-38 µm) and ultra-fine (-20 µm) size fractions.

The application of two pilot G-14 cells in open circuit demonstrated the ability to recover the fine and ultra-fine gold loss to the tailings, with the G-cell achieving an average concentrate grade of 19.94 g/t with an addition of plus-40% gold recovery from the tailings. Size-by-size analyses from the same gold operation showed it was possible to achieve an additional recovery of 65% and 68% in the size fractions of 0-20 µm and 20-38 µm, respectively.

Tailings treatment

Reacting to the critical need to reduce waste in tailing ponds and maximise recovery of valuable minerals, **Clariant**, in 2020, launched a suite of new tailing flotation products for the treatment of slimes.

The solutions, which included those from the FLOTIGAM™ and FLOTINOR ™ range, are geared towards improving iron ore recovery.

FLOTIGAM 7500 is a sustainable flotation collector for the removal of quartz and other silicate minerals from iron ore. Based on its new technology, a more selective adsorption at these gangue minerals' surface is achieved, providing improved flotation performance in terms of iron recovery and concentrate grades, according to Clariant. It is a robust product that can sustain plant variations and keep operational targets under control, also allowing the production of iron concentrate within market specification with a better cost-benefit outcome than other industry solutions.

FLOTINOR 5530, meanwhile, is a collector developed for iron ore slimes flotation.

Typically, the iron ore concentration process requires the step of desliming to remove ultrafine particles that damage conventional flotation performance. However, at this fraction, there are still high contents of valuable iron minerals that, in most processes, are sent to the tailings dam as waste material, Clariant says.

This slimes fraction, instead of being disposed at the tailings dam, can pass through a flotation step. Gangue minerals, mainly quartz and kaolinite, are floated and the iron mineral, mainly hematite and goethite, are kept in the concentrate, thus presenting as a commercial product, Clariant explained.

FLOTINOR 5530 presents not only economical benefits that come with increasing the overall iron recovery at the processing plant; it also has environmental benefits by reducing the amount of tailings generated by an iron ore processing plant, the company said.

Alongside these iron-related innovations, two HOSTAFLOT™ products were advanced by Clariant in 2020.

These xanthate replacement technologies provide mining operators with a safer and more sustainable alternative to xanthate collectors, allowing mining operators to discontinue the use of xanthates, which can come with fire and

explosion hazard risks.

These alternatives, which Clariant developed through collaboration, offer a high copper flotation performance, safer handling and disposal, reduced capital expenditure and a longer shelf life than xanthates, according to the company. IM