

Chemical balance



John Chadwick covers some of the news, new formulations and new ideas in the use of chemicals

The global mining chemicals market is expected to reach \$38.01 billion by 2024, according to a recent report by Grand View Research. It says “positive mining industry outlook in India, China, Australia, Peru, and Chile is expected to drive the market over the forecast period. The presence of abundant raw materials including rare earth metals in China, Russia, Australia, Thailand, and the US is expected to facilitate exploration activities, thus propelling demand for the product.

“Australia has the third largest rare earth metal reserves in the world. In Russia, companies have been investing increasingly in the development of new extraction techniques to recover uranium. These factors are likely to have a positive impact on growth. Decrease in ore quality of zinc, lead, copper, and nickel is expected to promote utilisation of sophisticated technologies requiring frothers, flocculants, grinding aids, and solvent extractants.”

Grinding aids dominated the global market accounting for over 40% of the global market share in 2015. Grinding aids help in improving the extraction process and require low maintenance. In addition, use of grinding aids can reduce pollution and other harmful effects on the environment. Increasing concerns regarding the cost of grinding the minerals is expected to increase use of grinding aids over the forecast period.

Explosives & drilling applications dominated

the market in 2015 and are projected to be the fastest growing segment.

Asia Pacific accounted for over 40% market share in 2015 and is projected to witness the fastest growth on account of the rapid industrial development and increasing focus on sustainability. Market players have been investing increasingly in the mining industry in the region which is expected to have a positive impact on demand for mining chemicals.

Clariant has made a number of investments which increase the footprint of its Mining Solutions business and further improve its product portfolio, customer base and technical expertise, it reports. Firstly, the company has acquired Chemical & Mining Services, a provider of specialty chemicals and technical services to mining industry clients located primarily in Australia. Secondly, Clariant has also acquired the speciality mining chemicals business from **SNF Flomin**, a US-based subsidiary of the SNF Group which manufactures and distributes reagents for the minerals processing industry.

Additionally, Clariant Mining Solutions has opened a new facility and expanded one of its current facilities in North America. The company has inaugurated the Mining Application and Development Center in Tucson, Arizona and this is now the regional hub for mining research. The close proximity of Clariant to key mining customers will allow for more and better cooperation on customised products and

Ucore Rare Metals is purchasing the outstanding shares of IBC. IBC is a world leader in Molecular Recognition Technology (MRT) for the mining industry, with an existing customer base spanning several continents

solutions. Furthermore, its current facility in Reserve, Louisiana, has been expanded and is now able to also blend chemicals for the mining industry. The additional production location allows Clariant to improve its customer service thanks to a stronger and more secure supply chain.

“These investments strengthen our global position as a leading supplier of specialty chemicals to the mining market. Chemical & Mining Services current business and products are a complementary strategic fit to our own and also provide us with specialised technical expertise. SNF Flomin, while US-based, supplied to customers worldwide and thus allows us to expand geographically and serve our customers with an increased product and service portfolio. Finally, the investments in North America enable us to become a stronger player in this region’s mining market and better support our customers by stepping up both our research and supply chain capabilities” said John Gordon, Global Head, Clariant Mining Solutions.

In its first quarter report, Clariant stated “Natural Resources sales grew by 17% in local currency and reached CHF 347 million, bolstered by acquisitions. In the difficult industry



Clariant Mining has many years of experience in modern explosive emulsifier technology

environment, the underlying Oil and Mining Services sales were slightly negative, but were helped by acquisitions. Functional Minerals continued its solid growth development. Sales in Catalysis were up by 2 % in local currency to CHF 142 million with a soft demand recovery in the Asian and European markets.”

BASF's Mining Solutions business has been able to improve gold processing circuits around the globe and has recently been active in West Africa. One key to success has been the extensive test work and benefits that Rheomax® DR1050 has provided.

The first visit to Ghana took place in 2014. After systematic visits and laboratory evaluations, DR1050 was found to give promising performance in thickeners, and plant trials were conducted in 2016. The trials showed a significant reduction in tailings volume and polymer consumption. Unlike in many other African countries, water scarcity is not as big a challenge in Ghana. However, the cyanide leach process defines strict environmental limitations and water reuse is essential for the process circuit.

A pre-leach thickener (PLT) was performing well with the incumbent flocculant, but due to solution make-up station limitations a new flocculant was introduced. DR1050 was found to be very reactive and very dose-effective. The dose requirement was over 30% lower. The objective was to keep underflow density as stable as possible, which was successfully achieved.

Feed slurry from CIL leach tanks is washed in counter-current decantation (CCD) circuit, which consist in this case of two thickeners. Underflow densities had been too low and solids had been run off to a process water pond. Due to volume

constraints in the process water pond, the focus was to improve CCD2 underflow density. This would minimise the water outlet to tailing storage facilities and improve water recovery and reuse in mining operations.

With Rheomax DR1050, it was possible to achieve ~7% higher underflow densities without compromising rake torque and underflow pumping. This improvement corresponds to close to 300 m³/h less water to tailings facilities.

Simultaneously, the flocculant dose amount was decreased by 30%.

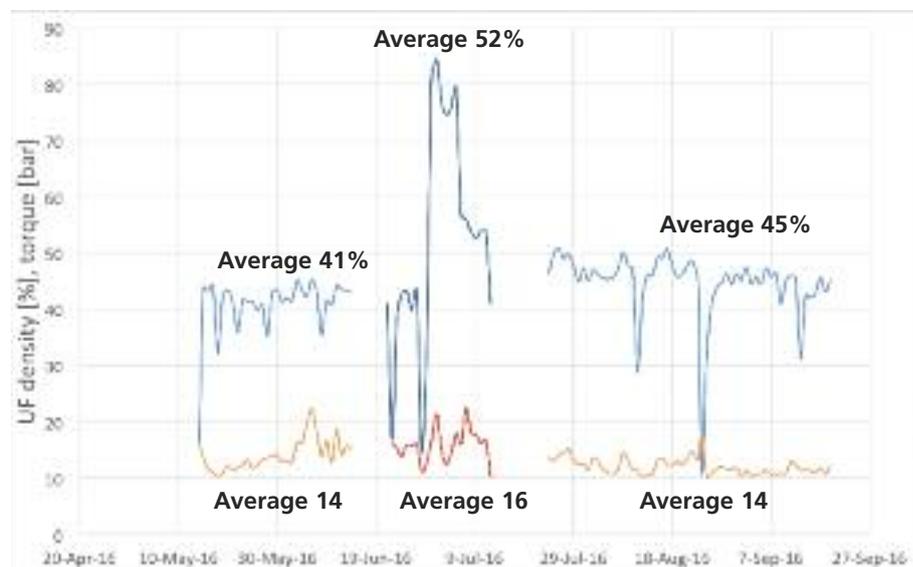
In previous studies, it has been found that Rheomax gives a more stable performance and less process fluctuation.

The customer was happy with BASF's achievements and committed project team. The next step is an extended six-month trial campaign with improved process control to eliminate process variations as much as possible.

Reagents for harsh waters

The current focus of Flottec's research efforts is to understand how its reagents behave in harsh waters including sea water and brines. Frank Cappuccitti, **Flottec** President told *IM*: “Many new operations are faced with poor quality waters which greatly affect the flotation performance. We have created new reagents for control of soluble activating ions in solution in harsh water and conducting research on how frothers behave in these types of water. Previous research has shown that ionic strength of the water creates small bubbles without frother. So frothers are needed more for their froth creation than bubble reduction properties. Initial observations show that frothers seem to be less strong in harsh waters than fresher waters. Our research work this year will centre on understanding the mechanisms of frother behaviour in harsh waters and determining how the chemistry of frothers need to be modified for these types of conditions.”

Another focus area is on better hydroxamic acids. Over the last several years, there has been a renewal of interest in hydroxamic acids for rare earth, niobium and copper oxide flotation. The aromatic hydroxamic acids have shown to be the best products for rare earth and niobium flotation but their cost and handling properties have been a barrier to use. “This chemistry provides a much higher degree of selectivity and recovery that is necessary to make rare earth separations economically feasible. The alkyl hydroxamic acids are generally more suitable for copper oxide flotation. Flottec research has focused on creating hydroxamic acids that have better physical handling properties than previous products and come in both liquid and dry forms that are easily made into solutions for use in plants.”



Underflow density and thickener rake torque in CCD2 thickener during trial period. Rheomax DR 1050 period in the middle

Cappuccitti adds that great progress has also been made in the understanding on how reagents effect flotation hydrodynamics and therefore, flotation performance. “In recent work that we conducted, we have shown that all reagents have some form of hydrodynamic characteristics. But we also concluded that although some collectors have frothing properties, when frothers are added, their properties dominate. This same work has provided even more convincing evidence that particles of different sizes float best when the pulp is at the minimum bubble size which occurs at the CCC of the particular frother and air rate used. The idea that small bubbles are needed for small particles and large bubble for large particles may not be true. What is more important for flotation of fines versus coarse is the actual strength of the frother – weak frothers for fines, stronger frother for coarse. This understanding makes it much easier to design flotation circuits to improve recovery of all sizes of materials.”

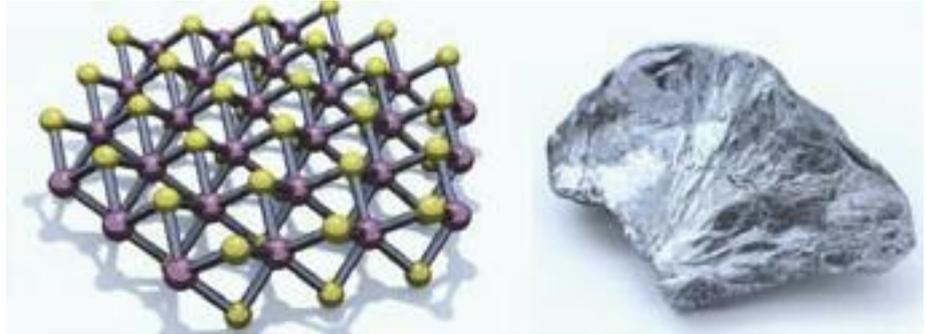
Finally, another area of focus by Flottec is the use of reagents to control gas hold up in the flotation circuits. “It is becoming evident that gas hold up in the cells is a prime driver of performance and therefore, if it can be measured and controlled, the circuits can be better operated at optimum conditions. Further work is required and planned in the next year.” *More information on this work that is progressing on the control of flotation circuits will be featured in the November 2017 flotation edition of IM.*

Recovering high-tech metals

Solvay’s CYANEX® 272 is a phosphinic acid-based SX reagent used commercially to recover and purify cobalt from sulphate solutions. Solvay has previously developed CYANEX 272-specific SX modelling software to assist operators in the design and optimisation of their circuits. The modelling software has enabled determination of the ideal reagent concentration, staging configuration, and pH profile in circuits operated with mixbox pH control.

Solvay’s recent advances in modelling capabilities have allowed the simulation of circuits without direct mixbox pH control. During extraction, the use of preneutralised reagent creates a natural pH drift within the circuit similar to the ideal pH profile attained using mixbox pH control. A similar pH drift occurs in scrub circuits using acidified water as the scrub-feed solution. Modelling has indicated that circuits operated without mixbox pH control can achieve the desired metal separation while simplifying the commercial operation significantly.

Since the active component of CYANEX 272 extractant is a phosphinic acid, metals are extracted through a cation exchange mechanism.



Although CYANEX 272 extractant is selective for cobalt in the presence of nickel, a variety of other cations can also be extracted depending on the solution pH. CYANEX 272 extractant is totally miscible with common aromatic and aliphatic diluents, and is extremely stable to both heat and hydrolysis.

CYANEX 272 was reviewed at ALTA 2017, as was *Economical precipitation of cobalt and nickel from solution* by **Glencore Technology’s** Paul Voigt, Mike Hourn and Glenn Stieper.

“As mine head grades decline and orebodies become more complex, they explained, “traditional mineral processing techniques and flowsheets to achieve saleable concentrate from these ores becomes more difficult. Mines with lower quality concentrates or concentrates with penalty elements are at particular threat. The economics of these operations are far more susceptible to metal price and the availability of other, cleaner concentrates. Additional value may be realised through improved recovery by the inclusion of low grade middling concentrates at the expense of lowering the overall concentrate grade.

“The most cost effective way to reduce impurity levels is to do so as early as possible in the mining value chain. Established technologies such as fine grinding and fine particle flotation are well established as effective methods in mineral processing unit operations. What is normally overlooked is how a hydrometallurgical process could also be integrated to achieve higher concentrate upgrade at the mill. In the base metals environment, this is mainly because hydrometallurgical processes are associated with production of metal or use of expensive and toxic precipitating agents once the minerals of interest are solubilised. These ‘back-end’ processes can be very expensive particularly with power constraints and the high capital cost associated with low metal tonnes.

“In response to this, Glencore Technology has developed an alternative method for recovering economic minerals once leached into solution rather than relying on conventional flowsheet options. The method involves the precipitation of base metals in the sulphate system from solution with limestone or lime. The final grade of the precipitate is not usually high enough to attract

Solvay also offers CYANEX 600 for molybdenum; CYANEX 572 for rare earths; CYANEX 301 for cobalt and nickel co-extraction and CYANEX 921 and 923 for other applications

favourable terms of sale due to dilution from gypsum and sulphate salts. A set of operating conditions have been developed to allow the separation of the base metal precipitate from gypsum by exploiting the difference in particle size producing a high grade concentrate at low cost. This process was originally developed by Glencore for the application of zinc and copper systems.”

The paper reports on the successful application to nickel and cobalt which had significant advantages over the incumbent precipitation process utilising magnesia.

There are in excess of 400 Mt of accumulated copper slags around the world, with grades ranging from 0.6% to as high as 1.7% Cu, as well as significant grades of gold and silver. Slag is costly and problematic to retreat by conventional process technology, so it tends to be indefinitely stockpiled or sold off as a construction material, reported Tim Newton and Frank Trask of **Mining and Process Solutions (MPS)**, Australia at ALTA 2017. In the paper *The recovery of copper and precious metals from smelter slags by alkali glycine leaching*, they explain that “alkali glycine leaching technology offers a new approach to retreatment of slag. Glycine can selectively extract copper, gold and other valuable components while ignoring iron-rich gangue minerals. Metals can be recovered from leach solutions by conventional downstream methods. Glycine losses are minimised by recycle of barren liquor to the leach circuit.”

Following a metallurgical test program, MPS has developed a process to treat slag from a South American operation. Test results and a conceptual process design are presented herein along with indicative capital and operating cost estimates. Comparison with alternative processes shows a strong economic basis for further development.

Cyanide

In a paper, *The RECYN process - changing the negative public perception of cyanide*, presented at ALTA 2017, Malcolm Paterson of **PT Green Gold**

Engineering, Indonesia, noted that “cyanide is firmly established in the gold mining industry as the overwhelming choice of solvent for gold and silver recovery from ores. Several niche applications for alternative reagents have been proposed, but it’s unlikely the superiority of cyanide will be seriously challenged for some time.”

His paper describes a development that can help change the negative perception of cyanide in gold plant processing and, at the same time, substantially improve the economics of its use.

The RECYN process is a resin based technology that allows for the economic recovery of cyanide from gold/silver plant tailings. The process is also used to recover dissolved base metals and gold/silver cyanide complexes. The combination of recovery steps overcomes any need for further detoxification of the tailings, changing a nett cost to a positive return.

The advantages he puts forward are that: “Gold projects incorporating the RECYN process can reduce the purchase and shipment of cyanide by 50%, reduce the overall cost of cyanide usage, and produce a fully decontaminated tailings stream from the process plant. These advantages, both economic and environmental, can help change the negativity associated with cyanide.

“The Mirah gold project in Central Kalimantan, Indonesia has, for over two years, successfully operated a commercial scale plant (1Mt/y ore) for the recovery and recycle of cyanide on a continuous basis. An average of 1t/d of NaCN has been recycled at a cost of 50% of new cyanide, with no further detoxification of the tailings required to meet environmental compliance levels.

“A second project is presently under construction, designed to recycle 1.5t/d NaCN, incorporating many improvements in operation and efficiency acquired from the first project.

“We believe the RECYN process is now sufficiently robust for wider international commercialisation and will become a standard part of the gold process plant flow sheet.

On February 22 this year the **International Cyanide Management Institute (ICMI)** re-certified Orica’s cyanide manufacturing facility in Yarwun, Australia as compliant with the Cyanide Code. The facility was initially certified in November 2006.

Orica is a global leader in the manufacture and distribution of sodium cyanide to the mining industry and says it is “committed to delivering and maintaining the highest standards for the safe manufacture, transport and use of sodium cyanide. In order to achieve compliance with the cyanide code, Orica’s manufacturing plant was audited by an independent organisation, finding Orica to be in full compliance with the code.”

The International Cyanide Management Code for the Manufacture, Transport, and Use of Cyanide in the Production of Gold (Cyanide Code) was developed by a multi-stakeholder Steering Committee under the guidance of the United Nations Environmental Program (UNEP) and the then-International Council on Metals and the Environment (ICME). The code is a voluntary industry program for gold mining and services companies, which focuses exclusively on the safe management of cyanide.

With effect from January 1, 2017, ICMI extended the Cyanide Code to include the production of silver from primary silver mines that use cyanide in the production process. The producers and transporters of cyanide used in primary silver production will be included in the expanded program.

A primary silver mine is defined as an operation where silver is the main commodity produced. About 30% of the world’s silver production comes from primary silver mines; the balance is produced as a co-product from polymetallic, base metal, or gold mines.

The gold industry’s implementation of the Cyanide Code continued to expand in 2016, and the program has had a net gain of 17 signatories, a 9.5% increase over 2015. Through December 16, ICMI has accepted applications from 27 new signatories in 2016, while 11 signatories left during the year. The 196 signatories now participating in the program include 46 mining companies, 22 cyanide producers, and 128 transporters.

The new signatories in 2016 consist of three mining companies and 14 transporters. With a fourteen-fold growth in signatories since the program’s 2005 launch, the Cyanide Code is now being implemented in 51 countries on six continents.

The growth in certified operations also has continued over this year with 23 certifications and 50 recertifications announced by mid-December 2016. Initial certifications show that the program continues to attract new participants, while recertifications indicate the ongoing commitment of signatory companies to employ best practices for cyanide management.

During this year, the program also has reached new levels of certified operations. By December 16, 269 of the 344 signatory operations (78%) were certified – a new high – which reflects that the Cyanide Code is now an established and mature program. More than 48% of the total operations participating in the Cyanide Code program are recertified, and, notably, over 58% of the gold mining operations in the program (77 of 133) have been recertified, which shows the considerable efforts of signatories to maintain continuous compliance.

Cyanide alternatives

Is alkaline glycine a contender for copper? asked Mike Dry of **Arithmetek Inc**, Canada, at ALTA 2017.

Work is being done on the use of alkaline glycine as an alternative to cyanide for the extraction of gold and silver from ores and concentrates. “In particular, he noted, “the indications are that, where copper is present, alkaline cyanide may well offer lower processing costs than conventional cyanidation. Another avenue that is being investigated is the application of alkaline glycine to the extraction of copper from ore or concentrate containing copper sulphides.

“A recent review shows that when the copper concentrate meets the requirements for smelting, smelting remains economically superior to hydrometallurgical processing. The same review, however, also points out that copper concentrate grades are declining, and that an increasing share of the world’s copper production will not be amenable to pyrometallurgy. At present, pressure oxidation (POX) is the dominant hydrometallurgical option, but several other hydrometallurgical processes are under development.

“A new hydrometallurgical approach to the extraction of gold, silver and copper from various sources has recently been proposed. This approach uses alkaline glycine as the lixiviant, and a fair amount of exploratory laboratory-scale work has been presented.”

His paper presents an early-stage evaluation of the process economics potentially associated with the application of alkaline glycine to the processing of copper sulphide concentrate that is not amenable to smelting because of its high arsenic content. This work uses process and capital cost modelling to generate preliminary generic financial models for two circuits:

- Conventional POX processing, in which the sulphide is oxidised in an autoclave
- A circuit using the proposed alkaline glycine chemistry.

The paper presents the results of a comparison between the established technology and new technology via preliminary estimates of the capital and operating costs and simple cash flow analysis leading to return on investment numbers.

Molecular Recognition Technology (MRT)

Ucore Rare Metals has entered an option to purchase agreement with IBC Advanced Technologies, whereby Ucore has an option to purchase the outstanding shares of IBC.

This Option to Purchase Agreement is a major milestone for Ucore” said Jim McKenzie, President and CEO of Ucore. “IBC is already a world leader in MRT for the mining industry, with an existing customer base spanning several continents and including majors such as Asarco



Grupo Mexico (USA), Impala Platinum of South Africa, Tanaka Kikinzoku K.K. of Japan, Sino Platinum of China and LS Nikko of Korea. Remarkably, this initiative places us in a position to assume and accelerate a business platform that IBC has established over almost 30 years in business.”

“IBC and Ucore offer a high degree of synergy as a combined entity,” continued McKenzie. “IBC brings with it an unsurpassed expertise in this revolutionary nanoscience, plus existing infrastructure, operational and production expertise, and an extensive existing customer base. Conversely, Ucore and its personnel bring a wide-ranging background in the financial markets, IP licensing regimes, and the scaling of proven technology platforms for accelerated growth. All of this comes at a time when disruptive materials technologies are transforming prior business models in the fields of transportation, energy storage and supercomputing. The opportunity to guide this change is significant.”

“The IBC intellectual property and know-how comprises dozens of customized molecules in the existing SuperLig® product catalogue,” said Peter Manuel, Vice President & CFO of Ucore. “SuperLig is an advanced nanotechnology. It represents best-of-breed American materials science and innovation, capable of appropriating metals in polymetallic environs with high precision, selectivity, speed and recovery. IBC and Ucore benefit from the advisory expertise of Dr Reed M. Izatt, molecular recognition pioneer and Professor Emeritus of Brigham Young University, USA, as well as Dr Jean Marie Lehn, Nobel Laureate and a Director of the Institut de Science et d’Ingénierie Supramoléculaires of the Université de Strasbourg, France. We’re honoured to be in the company of these giants in the field of macrocyclic science.”

The Japanese Government (Mitsubishi Research, Inc.) recently awarded to IBC a highly competitive subsidy grant, Demonstration Project for Seawater Purification Technologies, concerning the selective separation of the radionuclides strontium and caesium from contaminated seawater at Fukushima, Japan.

IBC’s expertise is illustrated by its extensive development and commercialization of separations systems for PGMs at a world level. PGMs are analogous to the rare earth elements, in that they are considered difficult to selectively separate due to their constituent chemical similarities.

The Ucore-IBC alliance builds on IBC’s proven capabilities to develop, scale-up and commercialize selective separations systems for a number of diverse and complex applications.



ArrMaz process consultation - examining froth characteristics for maximum recovery and grade

Ucore is focused on rare metals resources, extraction and beneficiation technologies with near term potential for production, growth and scalability. In March 2015, Ucore announced the right to acquire a controlling ownership interest in a joint venture with IBC to deploy the exclusive rights to SuperLig technology for rare earths, multi-metallic tailings processing applications, and select PGM recycling applications in North America and associated world markets. Ucore has a 100% ownership stake in Bokan- Dotson Ridge. In March Ucore announced the unanimous support of the Alaska State Legislature for the investment of up to \$145 million in the Bokan project at the discretion of the Alaska Import Development and Export Agency.

Water treatment

Kemira has launched a new high performance cationic flocculant, specifically engineered for sludge dewatering applications. The Kemira Superfloc® XD-7600 polymer is designed to help customers decrease their total cost of ownership through more efficient sludge handling, including freight and disposal costs. The dry product also minimises storage and transport costs. XD-7600 significantly improves cake solids and filtrate quality compared to conventional cationic polymers and is effective at low dosage levels.

“After several full-scale trials at various wastewater treatment plants, I’m pleased to say this product shows exceptional dewatering performance in liquid-solid separations with a wide range of sludge conditions,” says Wido Waelput, Senior Vice President at Kemira. “This is the first one in a range of innovative premium polymers we are launching this year, thanks to our intensive R&D work in very close

collaboration with our customers.”

Phosphate optimisation

Todd Parker, Global Marketing Manager Mining, **ArrMaz** explains that “mining chemicals are essential to creating such value throughout the phosphate fertiliser supply chain.

“At the beneficiation plant, optimising phosphate grade and recovery is critical to phosphoric acid and fertiliser production processes, as it influences not only end product cost, but also quality. Since 1967, ArrMaz has been serving the process and functional chemical needs of the phosphate industry to improve ore grade and recovery.

“While there is no universal reagent scheme and flowsheet design, each directly influences the other. Therefore operations designed with a marriage of flowsheet, equipment selection and reagent formulation creates the best value for the miner.

“ArrMaz develops custom reagent schemes and flowsheet designs for customer-specific phosphate ores to recover more, higher grade phosphate while consuming less energy and resources, and extending mine life. We provide a complete technical service package that includes laboratory evaluations of flowsheets and reagents as well as process consultations on existing operations, and custom formulated reagents to improve recovery and grade for phosphate processing operations around the globe.

“The ability to recover fine fractions can also significantly improve operational economies, extend mine life, and reduce the demand for clay and tailings impoundments. However, handling and recovering finer phosphate fractions can create a balancing act between overall recovery and conditioning/flotation efficiency. Oftentimes clays interfere with the flotation process, driving costs up and challenging the recovery of other size fractions. In this case, reagent selection is key. Unique to ArrMaz are our CustoFloat® and CustAmine® reagents formulated to handle clays and multiple sized feed fractions. These reagents have recently found success for carbonate and silica rejection in clay-laden feeds while maximising grade and recovery.”

ArrMaz’s custom formulated PEG and DF series of defoamers can reduce operational inefficiencies caused by foam and entrained gases, improve evaporator efficiency, and increase throughput. Better rock combined with ArrMaz filtration aids lead to improved filtration rates. The combination of the right defoamer and the right filtration aid creates gypsum crystals that are easier to filter, increasing filter capacity and reducing filtration losses. This in turn translates into higher grade phosphoric acid for phosphate fertiliser production.

“Our granulation and colouring aids improve hardness, roundness, colour and appearance,” Parker continues, “leading to improved quality recognition by the fertiliser market. ArrMaz’s DUSTROL® coating agents significantly lower dust generation and caking (pile set) during storage and handling, reducing environmental concerns and improving worker safety. **IM**



WATER MAINTENANCE



