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SULPHUR Number 401 www.sulphurmagazine.com July | August 2022

Number 401

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SULPHUR

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Southern Africa's acid industry

Base metal smelting

Advanced SRU catalysts

Condensate formation in acid plants

SULPHUR
ISSUE 401
JULY-AUGUST 2022

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Cover: *Sulphur pastilles.*
Andrei Dubadzel/Shutterstock.com

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Where is oil going?

The past couple of years have been quite the wild ride, with major global events dominating markets outside of the usual concerns of broad market supply and demand. It seems like a long time ago now, but this time last year, the price of a barrel of Brent crude was about $75. Go back two years, in the wake of the onset of covid restrictions, and that barrel would have cost you $40 (and just $25 a couple of months before that). In the wake of Russia's attack on Ukraine, you could easily have paid $130, and it has been hovering around $110/bbl for the past few months. The last time oil spent any time at that level was in 2014, just before the Chinese economy ran out of steam and prices slumped by 70%.

So where is oil going now? As is often the case, there are no shortages of opinions on the matter. If you believe a recent JP Morgan Chase report, in response to the G7 toying with the idea of capping the price of oil from Russia to try and deny Moscow the funds to continue waging its war, Russia could decide to tighten supplies to Europe in the autumn and winter to try and gain leverage over Ukraine negotiations, and prices could soar to $190/bbl if output was cut by 3 million bbl/d, or the incredible figure of $380/bbl if the cut was by a "worst case" amount of 5 million bbl/d. On the other hand, if you believe Citigroup, then many countries are already in recession, with demand falling, and oil could drop to $65/bbl by the end of this year, and $45/bbl by the end of 2023. Well, between $45 and $380 is quite a range, and it's probably safe, though undeniably unhelpful, to say that the true figure will be somewhere between the two! For the record, most analysts are still predicting a price of somewhere between $80-110/bbl for this year.

> **"For refiners, meanwhile, these are good times..."**

What is certainly true is that OPEC has agreed to increase its August quota figure by 650,000 bbl/d, and Brent prices at the start of July had already dropped below $100/bbl, as the prospect of recession started to become more real, and the continuing Omicron outbreak in China continues to lead to major restrictions on movement. Russian oil continues to sell, mainly to China and India, at a discount of up to $30/bbl to ensure sales. The prospect of recession seems inevitable, with central banks chasing inflation by monetary tightening in spite of positive economic signs like near-full employment and continued job growth. The supply shock caused by the war has not been as bad as expected, and Russia may feel it's doing well enough at current prices to try not to rock the boat by shutting off supplies to Europe. We may be heading to somewhere closer to the Citigroup forecast than the JP Morgan one.

For refiners, meanwhile, these are good times – US refineries have been operating at or near maximum utilisation levels in recent weeks as demand recovers. Petroleum stocks are sitting at multi-year lows, and with gasoline prices at the pump high, refining margins are at unheard of levels – $35/bbl in the US, and reportedly up to $40/bbl on gasoline and $50/bbl on diesel in the UK. US refinery utilisation is at 95%, the highest level since before covid. And they can add to that the extra cash from sulphur – at levels of $400-500/t, they are more than double that of this time last year, and more like six to eight times that of July 2020, though seemingly finally on their way back down as phosphate producers begin to balk at such price levels.

In sulphur, at least, supply is usually slightly more predictable, and new sulphur recovery projects are in the process of completing which will raise output levels at the same time that phosphate demand is contracting. In theory, the next year ought to see prices back down to more familiar levels. But then, that was what we thought last year as well!

Richard Hands, Editor

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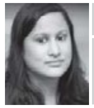
Price Trends



MARKET INSIGHT

Meena Chauhan, Head of Sulphur and Sulphuric Acid Research, Argus Media, assesses price trends and the market outlook for sulphur.

SULPHUR

The global sulphur market has reached a peak and started to correct following an 18-month long bull run. This peak has come on the culmination of a number of factors. Prior to the start of the conflict in Russia and Ukraine, the sulphur market appeared to already be close to reaching a peak, with a softer sentiment emerging in the downstream phosphate fertilizer market. But fears over potential disruption to supply from the Russia and Central Asian region led to another spike in pricing, beyond previous expectations. In the months that followed, sulphur originating from Kazakhstan has continued to be transported via Russian rail to ports for the export market, with the disruption that had been expected not emerging. Russian sulphur exports have been disrupted, but previously agreed shipments to key markets continued through the first half of the year. At the same time, demand side fundamentals led to a slowdown in consumption, and this has impacted import demand. With significant downward pressure from the DAP market which turned to a bearish sentiment, sulphur prices began correcting in June. Expectations for further softening in DAP prices will likely lead sulphur prices to further decreases albeit at a slower rate.

Middle East prices decreased by around $60/t through June but prices at the end of the month were still around $121/t above prices at the start of the year and more than $200/t higher than a year earlier. Kuwait's KPC set its July sulphur lifting price at $427/t f.o.b., down by $63/t from the June price. Muntajat set its July Qatar sulphur price at $428/t f.o.b. Ras Laffan/Mesaieed, down by $62/t from the June QSP of $490/t f.o.b. These decreases have come on the back of the lack of appetite from buyers in key markets and the weakening fertilizer market. In June, Adnoc/UAE was in negotiations for supply for the third quarter. Market sources quoted a $420/t f.o.b. Ruwais price for the third quarter concluded with some traders and end users. The July price had not been announced at the time of writing.

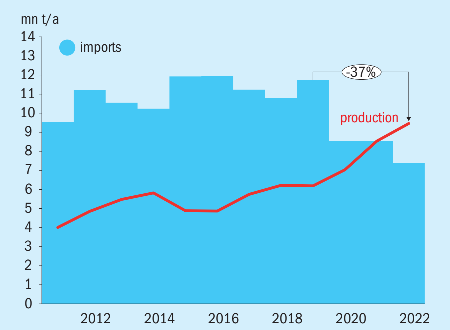
Third quarter contract negotiations for north Africa were under way in June for supply from the Middle East region, Kazakhstan via the Baltic and Black seas and Turkmenistan. Key consumer OCP has been absent from the spot market in the run-up to the third quarter contract settlements, in line with the seasonal trend. In Egypt, market participants reported small cargoes arriving from Russia placed some downward pressure on the north African price.

The China c.fr all forms range was assessed by Argus at $230-450/t c.fr at the end of June, with the low end reflecting molten product and the high end granular sulphur. Average prices dropped by around $63/t through the month of June but were around $100/t higher than at the start of 2021. Chinese imports dropped in January-May by 12% year on year to 3.2 million tonnes. South Korea and Japan were the leading suppliers in the first five months of the year. This marks a reversal in trend as Saudi Arabia, the UAE and Qatar have typically been the main suppliers. Sulphur imports from these three countries combined totalled 797,000t, down by 48% on the year. High sulphur prices are likely to have contributed to this shift, with molten sulphur prices being more attractive.

Other factors are the healthy rates of domestic production from the refining sector and the slowdown in the demand from the phosphates industry amid export restrictions. The Chinese benchmark is expected to fall further, in line with the global trend, during the second half of the year. The restrictions on phosphate fertilizer exports are a key factor for the forward view for import demand. But the continued increase in sulphur production in the domestic market will also put downward pressure on imports for the year. We currently expect Chinese imports to drop down to 7.4 million tonnes in 2022, this would reflect a drop of 1.1 million tonnes, or 13%, on 2021 levels.

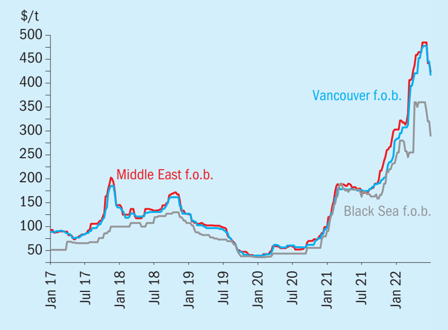
In capacity news, Chinese private-sector Shenghong Petrochemical started trial operations at its greenfield Lianyungang refinery, targeting commercial production late in the third quarter of this year when it will also be able to produce 420,000 t/a of sulphur. The refinery, located in Lianyungang, was previously expected to come on stream in March. But the start date was delayed as crude futures spiked to multi-year highs, preventing the refinery from building sufficient crude stocks for long-term operations.

Fig. 1: Chinese sulphur imports and domestic production



Source: Argus Sulphur Analytics

Fig. 2: Average sulphur prices, key export regions



Source: Argus Sulphur

Other capacity changes are concentrated in the Middle East region for the short term, with an additional 1.4 million tonnes of capacity expected online in 2022. Saudi Arabia, Kuwait and Qatar are all expected to ramp up projects, although available volumes for the market will likely be well below capacity rates. But the forward view remains a growth story for exports out of the region as oil and gas-based projects come to fruition at last.

SULPHURIC ACID

The global sulphuric acid market has been more stable on the pricing front compared to sulphur, but there has been a recent shift in market tone to bearish. Major export prices for sulphuric acid eased through June. NW European prices dropped by $5/t down to $210/t f.o.b. at the end of the month. This is around $18/t below levels at the start of 2021 but still $75/t above prices a year ago. There are still planned turnarounds at smelters in the second half of 2022 that will impact the market balance, potentially limiting the extent of further price softening. Umicore's Hoboken smelter in Belgium has a planned maintenance in November, lasting five weeks. Nyrstar also has a planned maintenance in the summer at its Auby, France smelter, lasting seven weeks while the company's Budel, Netherlands plant will undergo a 14-day turnaround. Meanwhile the Stolberg smelter in Germany is expected to come back online in the summer after its prolonged outage. Third quarter contract discussions were underway in June in NW Europe with early indications prices would rollover or see slight increases on the previous quarter. Logistics across the continent remain a concern with the shortage of truck drivers persisting through the second quarter.

While the Japan/South Korea export price remained stable at $138/t f.o.b. the China export prices dropped by $7.5/t to $1425/t f.o.b. over the month of June. China remains a major global exporter of acid and we expect availability to rise to 3 million tonnes for the first time in 2022. Exports have more than doubled in the first five month of the year, totalling close to 2 million tonnes. The leading market is Morocco, followed by Chile and India. Smelter acid capacity is forecast to rise by 2 million t/a in 2022 on last year, with copper smelters in development ramping up or coming online.

China's Daye Non-ferrous has delayed the commissioning of its 400,000 t/a copper smelter to the end of July or early August because of the impacts of the Covid-19 pandemic. The smelter had delayed the start-up to 13 June from late 2021 because of a delay in the shipments of its imported equipment and parts, owing to the pandemic. Daye Non-ferrous, located in Huangshi city in central China's Hubei province, is a subsidiary of state-owned China Nonferrous Metal Mining. Acid capacity at the smelter will eventually reach 1.5 million t/a.

Over in Latin America, the Chile price has dropped by $38/t since the start of the year but remains $90/t higher than a year earlier. Freights have been increasing and continues to support the delivered price in the short term. Codelco and the umbrella union representing its employees agreed to stop a planned strike at the end of June, which started after the company announces it plans to close its Ventanas smelter. Sulphuric acid capacity is estimated at 300,000 t/a. Chilean acid imports totalled 1.1 million tonnes in January-April 2022, up by 28% on the same period a year earlier. China is the leading supplier followed by Peru.

Higher operating rates at sulphur burners has provided support to the US market in June. The increase in sulphur production from US Gulf refineries has enabled acid producers to meet contract volumes and participate in the spot market, slowing the need for imported volumes. High imports earlier in the second quarter was needed to meet domestic demand during a period of maintenance.

The outlook for pricing for acid is complex because of the high costs many downstream end users are facing across a range of industries. Some regions have ample availability while logistics issues and costs are also a factor for the short term view. Rising freight prices are expected to support delivered ranges while putting downward pressure on export pricing in key markets. Copper prices dropped by around 17% over the past quarter on the London Metal Exchange (LME) and remained below $10,000/t while nickel was down 27%. Metal prices were also weighed on by strengthening in the US dollar at the end of June which makes purchasing more expensive in other currencies. ■

Price Indications

Table 1: Recent sulphur prices, major markets

Cash equivalent	February	March	April	May	June
Sulphur, bulk ($/t)					
Adnoc monthly contract	318	335	420	468	485
China c.fr spot	378	413	493	506	450
Liquid sulphur ($/t)					
Tampa f.o.b. contract	282	282	481	481	481
NW Europe c.fr	327	362	362	362	430
Sulphuric acid ($/t)					
US Gulf spot	238	238	238	238	238

Source: various

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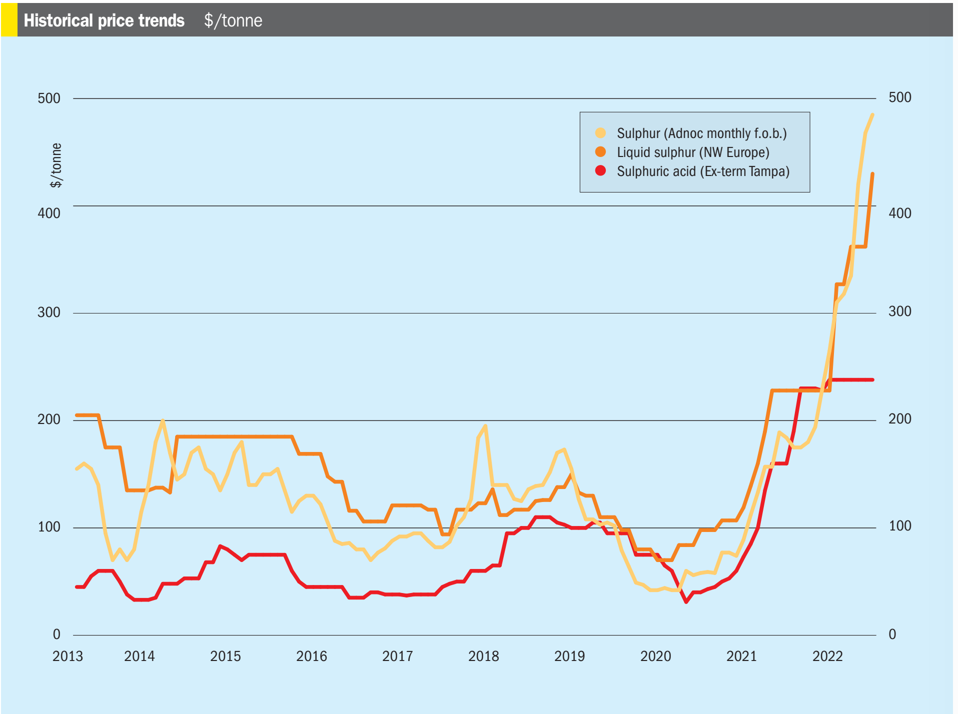
Market Outlook



Source: BCInsight

SULPHUR

- The ongoing recovery from Covid-19 has led to an uptick of sulphur from refineries in regions including the US compared with a year ago. As travel around the global improves, increasing fuel demand points to higher operating rates and improved sulphur recovery.
- Demand growth is expected to slow in 2022 on 2021 but the year ahead appears to have more potential because of new phosphoric acid capacity and strong growth in the metals sector. This will provide a floor to the correction in prices in 2023 as the market moves towards to a tighter balance.
- Major market import demand in Morocco, China, Brazil and India remain key to future pricing and trade. Domestic production increases in China and India will squeeze requirements but the demand boost in Morocco will mark a major shift in imports in the medium term.
- **Outlook:** The price correction is expected to continue through the remainder of 2022 with further decreases in 2023 on the back of a softening processed phosphates market and a move away from recent peak prices. While the outlook for sulphur supply from Russia remains a concern, rising capacity in other regions over the next year will more than compensate for the potential loss of tonnage to the export market.

SULPHURIC ACID

- Acid prices are not expected to correct to the extent that sulphur is in the short term. Acid prices have b een more stable through the second quarter, with less direct impact from the conflict in Russia-Ukraine. But, a correction is expected to persist going into 2023.
- Increased elemental sulphur availability in 2023 will lead to higher sulphur-based acid production, putting downward pressure on smelter acid prices.
- The rise in Chinese acid smelter capacity and production, alongside a slowing demand picture for the fertilizer sector domestically will maintain the country's position as a major acid exporter in the medium term outlook.
- The balance between sulphur and acid imports in Morocco will be changing in the outlook as OCP adds new sulphur burning capacity. Acid imports are expected to drop in the medium term as demand shifts towards sulphur instead.
- **Outlook:** Expectations are for some softening, with downward pressure from easing copper prices, sulphur and processed phosphates. But the rise in freight rates and turnaround schedule is likely to provide a floor to the correction. Strong metals output is expected according to guidance announced by producers in the year ahead, supporting the view for healthy smelter-acid production.

Sulphur Industry News

CHINA

Chinese refinery output falls due to covid

PHOTO: CHINA DAILY

PetroChina's Dalian Refinery, Liaoning Province.

Chinese refinery output has been steadily falling this year as covid-related lockdowns impact upon the economy. Figures from the National Bureau of Statistics showed that refinery output fell to 13.8 million bbl/d in April – down 2% year on year – then took a sharp fall in May to 12.6 million bbl/d, more than 10% down on the same time in 2021, when output stood at 14.1 million bbl/d. May's figure was 12.7 million bbl/d, a modest increase on April, but still 1.6 million bbl/d down compared to May 2021. Refining margins have also been hurt by high oil prices due to the Ukraine conflict, dropping close to zero or even negative according to industry estimates.

There is plenty of spare capacity which could export fuel into an international market desperate for refined product, but Chinese government quota restrictions prevent this. Chinese refining capacity was estimated at 17.5 million bbl/d in 2020 and could reach 20 million bbl/d by 2025 as more large scale refineries come on-stream, which would see China overtake the US as the world's largest refiner. Recent additions include Shenghong Refinery, and Hainan Petrochemical. However, large Chinese state-owned refineries were running at approximately 70% capacity in June, the lowest rate since March 2020, while smaller, private 'teapot' refineries were down to 50-65% as movement restrictions in Shanghai and other major cities took their toll on fuel demand. Vehicle sales were also down 50% on the same time last year.

SAUDI ARABIA

JGC wins Zuluf contract

JGC Holdings says that its JGC Corporation engineering, procurement, and construction business has been awarded the EPC contract for the Zuluf Central Processing Facilities by Saudi Aramco. Aramco is promoting the Zuluf Arab Heavy Development Program to meet growing global energy demand and is planning to increase production based on an additional 600,000 bbl.d of Arabian heavy crude. JGC has also received the contracts for the construction projects for the core onshore gas-oil separation plant and utility facilities including water injection facilities. The Zuluf project is part of Aramco's plan to reach 13 million bbl/d of oil production capacity by 2027, allocating a major chunk of its $40-50 billion capex budget for the project. The value of the JGC contracts is believed to be more than $3 billion.

NIGERIA

Tecnimont to install technology at Port Harcourt

Maire Tecnimont SpA says that its Tecnimont subsidiary has been awarded a front end engineering design contract by African Refineries Port Harcourt Ltd for a 100,000 bbl/d day refining plant, due to be operational in 2025. It will be built inside the existing Port Harcourt Refinery complex, where Tecnimont is already executing an EPC contract related to its rehabilitation works. The contract also includes a feasibility study for an independent section of the plant for the production of sustainable aviation fuel (also known as 'BioJet'), which will be based on NextChem's portfolio of green initiatives, using bio-waste as feedstock.

Alessandro Bernini, Chief Executive Officer of Maire Tecnimont Group and NextChem, commented: "We are really honoured to support Nigeria both in unlocking greater value by processing its natural resources and in developing circular economy for the first time ever in the country, as BioJet is one of the most effective solutions to reduce the carbon footprint of the global aviation industry. Moreover, these new contracts confirm the strong geographical diversification of our backlog and the reliability of our technology-driven value proposition."

UZBEKISTAN

Privatised refinery to be modernised

Sanoat Energetika Guruhi (SEG), Uzbekistan's largest private oil and gas company, has acquired the formerly state-owned Fergana Oil Refinery. The acquisition follows a competitive tender process as part of Uzbekistan's state asset privatization program, and forms part of SEG's evolution into a vertically integrated oil & gas company, covering upstream and downstream production, from exploration to full cycle processing of high-quality end products.

Shokir Fayzullaev, Chief Executive Officer of SEG, said: "We intend to modernise the Fergana Oil Refinery and double its capacity to two million tons of chemical products annually. By September 2023, the plant will produce Euro-5 gasoline and various modern types of oils and other refined products. Over the last twenty years, the need to modernise and invest in Fergana has been ignored, with the last modernisation being over 30 years ago. Now, as part of the SEG portfolio of companies, we have contracted best-in-class international companies Afton Chemical, Lubrizol, Infineum and Evonik, amongst others, for a full technical re-equipping of the plant."

SEG's modernisation programme includes licensing and engineering agreements with Axens SA and replacement of the hydrodesulfurisation unit, and commencement of Euro-4 and Euro-5 quality diesel fuel production via a modern gas desulphurisation unit. Future development will build the plant into a petrochemical complex, with oil production increasing to 1.6 million t/a by 2030.

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CANADA

HydroFlex chosen for renewable aviation fuel project

Topsoe says that its *HydroFlex* technology has been chosen for revamping the Braya Renewable Fuels refinery in Newfoundland. The refinery, bought by Cresta from the North Atlantic Refining Company in November 2021, will produce up to 18,000 bbl/d of renewable diesel and sustainable aviation fuel (SAF) initially and capacity will increase further in various stages of expansion. Start-up for production of renewable fuels is expected in the second half of 2022. The refinery's hydrocracker and diesel hydrotreater will be revamped to produce renewable diesel and SAF from various renewable feedstocks.

Henrik Rasmussen, Managing Director, The Americas, Topsoe, says: "We are proud to be part of this exciting refinery revamp with Cresta and to support their ambition to deliver renewable diesel and jet fuel for the local and global markets."

Chris Rozzell, Managing Partner at Cresta said: "We're proud to be associated with this new chapter for the refinery as it fully transitions from fossil fuels to the production of sustainable aviation fuel and renewable diesel fuels that will be critical to decarbonizing the aviation and heavy transport sectors. We also applaud the concrete steps the Government of Canada is taking to meet its climate objectives, and we look forward to a collaboration to position Braya Renewable Fuels to play a vital role in boosting the country's capacity to produce clean fuels."

INDIA

BPCL closes half of capacity for maintenance

Bharat Petroleum Corp Ltd (BPCL) has shut half of its crude processing capacity at its 240,000 bbl/d Mumbai refinery to carry out maintenance. The state-run refiner has shut a 120,000 bbl/d crude distillation unit and some secondary units including diesel hydrodesulphuriser and hydrogen generation units for 20-25 days, according to a statement by the company. Other units are functioning as normal. The refiner also plans to shut units at its 156,000 bbl/d Bina refinery in central India and 310,000 bbl/d Kochi refinery in the southern Kerala state later this year; the hydrocracker at Bina will be shot for 10 days in September for catalyst replacement, and a 210,000 bbl/d crude unit and secondary units including fluid catalytic cracking, vacuum gas oil hydro-treater, diesel hydro-treater, sulphur recovery unit and hydrogen generation units at Kochi will be down for 25-30 days for maintenance in September-October.

The Sakhavostokneftegaz refinery, Yakutia, Siberia.

PHOTO: SAKHAVOSTOKNEFTEGAZ

RUSSIA

Russian refinery output back up

Russian refineries processed 20.0 million tonnes of crude oil during May, up 9.3% from April, according to energy ministry data reported by Russia's Tass news agency, as refineries came back-onstream following maintenance, although this figure remains lower than the comparable period of 2021, which was 23.0 million tonnes. Russian refineries reduced processing in March and April in the wake of the invasion of Ukraine as international buyers avoided Russian products and as domestic demand was hit by a surge in borrowing costs and an economic slowdown. Processing in June was expected to remain around May levels. Some of the medium-sized refineries in southern Russia are likely to run at around 90%, but those away from ports will keep runs around 70%. However, throughput prospects remain uncertain amid lower exports of Russian products. The Russian parliament has proposed setting up a state fuel oil stockpile oil for the country's power generation companies and to address the country's excess fuel oil production.

Russia is also looking to increase domestic output of catalysts for hydrotreaters, hydrocrackers and FCC units. Prior to this year around 70% of refinery catalysts were imported, mainly from companies in Europe and the US which have now announced sanctions on these products.

Refinery expansions continue for now. Lukoil's Norsi refinery is in the process of completing construction of a deep processing complex, including a delayed coker, allowing the refinery to increase 10 ppm diesel output by 700,000 t/a. The complex includes 81,000 t/a of sulphur recovery capacity.

The Afipsky refinery is also in the process of modernisation, including a new hydrocracking unit and the sulphur recovery unit, Rosneft is planning construction of a hydrocracker at its Ryazan refinery, again including sulphur recovery capacity, and the Moscow refinery is adding a delayed coker, hydrogen and hydrocracker units, due for completion in 2025, again including sulphur recovery capacity.

UNITED STATES

GTC Vorro bought by MBT Technology

GTC Vorro Technology, a turn-key provider of environmental services and process technologies to oil & gas, refining, petrochemical and chemical companies, has been acquired by US-based MBT Technology, LLC. MBT was the former owner of GTC Technology Inc., which developed and licensed a wide offering of refining and petrochemical technology for the downstream industry. The company was acquired from PW Technologies and Vorro, LLC. GTC Vorro, based in Houston, says that it is now poised to expand its offerings in the sulphur removal and hydrocarbon processing industries. The company will operate in the upstream, midstream, and downstream industries, with a focus on environmental-friendly solutions for the hydrocarbon processing industry.

LyondellBasell may close refinery early

Reuters reports that LyondellBasell, which announced the closure of its Houston Refinery by the end of 2023 in April, could close the facility early if a major equipment failure affects processing units. The 268,000 bbl/d refinery can produce 89,000 bbl/d of gasoline, 44,500 bbl/d of jet fuel and 92,600 bbl/d of diesel from heavy, sour crude.

The US is facing a crunch in refining capacity, which was down to 18 million bbl/d in 2021, its lowest level since 2015 following closures during the covid pandemic, in spite of record fuel prices. There are expansions under way in Texas which could add 350,000 b/d of processing capacity, including ExxonMobil's BLADE (Beaumont light atmospheric distillation expansion) project at its 369,000 bbl/d refinery in Beaumont and at Marathon's South Texas Asset Repositioning (STAR) project at its 593,000 bbl/d Galveston Bay refinery. Valero also plans to start-up a 55,000 bbl/d delayed coker and sulphur recovery unit in 1H 2023 at its Port Arthur refinery. However, most US refinery investment is geared towards adding renewable fuel infrastructure.

PERU

Lithium project to produce potassium sulphate as by-product

American Lithium Corp. says that it has successfully precipitated high purity, fertilizer-quality potassium sulphate (aka sulphate of potash, SoP) by-product from the company's Falchani project. Testing confirms that in addition to high quality lithium compounds, SoP can be produced to potentially supply Peru with its domestic needs. The SoP produced from Falchani is 45% potassium and 20% sulphur.

Dr. Laurence Stefan, COO of American Lithium, said, "The strategic importance of the ability to produce significant amounts of SoP from Falchani cannot be overstated. This by-product will not only provide an additional potential revenue stream at Falchani, but more importantly will also provide a major source of domestic SoP for Peru with the potential to largely reduce the country's dependence on imported overseas fertilizers… to produce the high-value crops, fruit and vegetables that are major exports for Peru."

MALAYSIA

Land agreed for sour gas site

The Sarawak State government, via the Sarawak Economic Development Corporation (SEDC), has entered into a heads of agreement with Petronas, Shell and PTTEP for a long-term lease of land in the Petchem Industrial Park in Tanjung Kidurong, Bintulu, Sarawak. Both the land and Petchem Industrial Park belong to SEDC. The earmarked land will be leased to build an onshore plant complex which forms part of the Sarawak Integrated Sour Gas Evacuation System (SISGES) project. The development plan for the SISGES project is currently undergoing its final review process prior to the final investment decision by investors and the necessary statutory approvals.

Gas will come from the sour Lang Lebah gas field development, operated by PTTEP. The first phase of the facility will have a treatment capacity of 30 million cubic feet per day (cfd) at up to 10% acid gas removing hydrogen sulphide and carbon dioxide. H_2S levels are at around 0.5%, though CO_2 levels are much higher.

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Codelco's Ventanas site.

CHILE

Strike at Codelco briefly halts copper production

At the end of June a three day strike among working at Chilean state mining company Codelco paralysed copper output at the world's largest copper producer. The strike was in protest at the threatened closure of the Ventanas smelter, which was the site of an alleged leak of sulphur dioxide on June 6th. Chile's environmental regulator subsequently provisional measures for both Codelco and power company AES Chile after numerous people in the nearby towns of Quintero and Puchuncavi in central Chile, including hundreds of high school students and staff, showed signs of sulphur dioxide poisoning. The measures include the installation of a new temperature sensor to measure potential thermal inversions. Both companies have denied responsibility for the leak; Codelco says that its air quality stations recorded normal levels of SO_2 during the time of the incident.

President Gabriel Boric said that Ventanas had become "an embarrassment" and the board of state-owned Codelco ordered the smelter shut down after the incident and said that it would move towards permanent closure of operations at the site. Ventanas has had a troubled history, with numerous SO_2 leaks over the course of several years, including on in August 2021. The Quintero-Puchuncaví Bay, 160 km northwest of Santiago on the Chilean coast, is home to numerous industrial facilities including oil and chemical plants, and has been described by environmental activists as an "environmental sacrifice zone". However, in response to the announcement Codelco workers belonging to the Federation of Copper Workers Union began a strike at Ventanas and six copper mining facilities, describing the closure as "arbitrary" and blocking access to the sites by setting fire to tires, demanding that the government makes the required investment to bring the smelter up to higher environmental standards. Codelco moved to an agreement with the union to invest the required $54 million to reduce SO_2 emissions at the site after the government agreed to reinvest 30% of the company's profits from 2021-2024 back into its projects, with an aim to reduce borrowing requirements, freeing up cash.

Chile produces 8% of the world's copper, which represents up to 15% of GDP. The National Mining Company (Enami) has proposed building a new $1 billion smelter at Paipote in the Atacama region to replace output at Ventanas. ■

DEMOCRATIC REPUBLIC OF CONGO

Earthworks construction begins at Kamoa copper smelter

Ivanhoe Mines says that construction of earthworks has begun at the site of its new 500,000 t/a direct-to-blister flash smelter at the Kamoa-Kakula copper mining complex. The smelter will be large enough to process most of the copper concentrate forecast to be produced by Kamoa-Kakula's Phase 1, Phase 2 and Phase 3 concentrators, and will be built adjacent to the Phase 1 and 2 concentrator plants using technology supplied by Metso Outotec. In late 2021, Kamoa Copper awarded engineering company China Nerin Engineering the basic engineering contract for the planned smelter.

Once in operation, the smelter is expected to enable Kamoa-Kakula to reduce its cash costs per pound of copper produced by about 10% to 20%, due to significantly reduced transportation costs, as well as more favourable tax treatment, and the recovery and sale of sulphuric acid as a by-product revenue stream. There is strong demand for sulphuric acid in the DRC for copper leaching operations and copper mines in the region currently import significant volumes of sulphur used in sulphur-burning acid plants to produce sulphuric acid for the treatment of oxide copper ores. The DRC also imports sulphuric acid, primarily from Zambia.

The Phase 3 expansion of Kamoa-Kakula will make the mine the third largest copper producer globally, increasing yearly copper production capacity to about 600,000 t/a by 4Q 2024. Phase 3 will consist of two new underground mines known as Kamoa 1 and Kamoa 2, as well as the initial development at Kakula West. A new 5 million t/a concentrator plant will be established adjacent to the two new mines at Kamoa, taking total processing capacity to more than 14 million t/a. Going forward, the existing Phase 1 and 2 concentrators will be debottlenecked and operate at a combined throughput of 9.2 million t/a by 2Q 2023, which is expected to increase Kamoa-Kakula's copper production to more than 450,000 t/a.

Kakula is projected to be the world's highest grade major copper mine, with an initial mining rate of 3.8 million t/a at an estimated average feed grade of more than 6.0% copper over the first five years of operations, and 5.9% copper over the initial 10 years of operations. The Kamoa-Kakula Copper Project is a joint venture between Ivanhoe Mines (39.6%), Zijin Mining Group (39.6%), Crystal River Global Limited (0.8%) and the Government of the Democratic Republic of Congo (20%).

INDIA

Vedanta to sell Tuticorin smelter

Vedanta Ltd has put its 400,000 t/a Sterlite Copper smelter and refining complex at Tuticorin up for sale. The site includes the primary and secondary smelter complex, sulphuric acid plant, copper refinery, continuous copper rod plant, phosphoric acid plant, effluent treatment plant, 160 MW captive power plant, reverse osmosis units, oxygen generation unit and a residential complex with amenities. However, the request for expressions of interest comes while the company is still bogged down in a legal case in the Indian Supreme Court over the Madras High Court's decision to order the closure of the site for environmental violations, even though this was subsequently overturned by an environmental tribunal. The smelter has been

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closed since 2018 as legal cases progress through various courts.

Prior to its closure, the Sterlite smelter produced around 40% of India's copper requirements. Parent company Vedanta has also proposed setting up a 500,000 t/a copper smelter in a coastal location to help meet India's growing demand for copper.

AFRICA

Outotec to deliver electrowinning technology

Metso Outotec says that it has been awarded a contract for the delivery of advanced electrowinning equipment to a copper cathode production plant at an unspecified location in Africa. The value of the contract was put at €11 million. Metso Outotec's scope of delivery includes the supply of basic engineering and equipment for the copper electrowinning plant expansion.

UNITED STATES

Process to sequester CO_2 while producing sulphuric acid

Travertine Technologies, a new technology start-up based on research from the University of California at Berkeley, says that it has received $3 million in seed financing from the Grantham Environmental Trust and Clean Energy Ventures to enable the company to commercialise its novel process to capture and permanently sequester ambient carbon dioxide while producing sulphuric acid. The company says that the financing will allow it to scale up its team in Colorado and accelerate its pathway to pilot-scale technology implementation in 2023.

Travertine's electrochemical process processes waste sulphates such as phosphogypsum, a by-product of phosphate production, and mineralises CO_2 from the air as a carbonate precipitate while co-producing sulphuric acid, as well as 'green' hydrogen with potential use in renewable energy and oxygen. The carbonate permanently stores carbon in the solid phase, according to the company. For every tonne of sulphuric acid produced, around 500 kg of CO_2 is saved and sequestered.

Ground broken on secondary smelter

German-based Aurubis AG has broken ground on the United States' first large secondary smelter for multi-metal recycling at Augusta, Georgia. Total investment is estimated at $320 million, and the plant is expected to be fully operational by mid-2024. Once fully on-line, Aurubis Richmond will have the capacity to process about 90,000 t/a of complex recycling materials including printed circuit boards, copper cables, and other materials containing metals.

"We have doubled down on our commitments to use our technology and experience to become a forerunner for recycling valuable materials containing copper, nickel, tin, and other industrial and precious metals locally in the US," said Roland Harings, CEO of Aurubis AG. "The US currently produces about 6 million tons of recycling materials that contain valuable metals. We want to take advantage of this great potential and help ensure that these materials get reused. They are critical input materials for many industries in the US", said Roland Harings.

Itafos begins production of hydrofluorosilicic acid at Conda

Itafos says that it has begun production and sales of hydrofluorosilicic acid (HFSA) at its Conda site in Idaho. The company says that extraction and commercialization of HFSA is an organic growth opportunity to monetise the fluoride contained in Conda's ore. Conda has capacity of approximately 550,000 t/a of monoammonium phosphate (MAP), superphosphoric acid, merchant grade phosphoric acid and ammonium polyphosphate. The site's existing phosphoric acid evaporation process was modified so as to have the capacity to extract up to 30,000 st/a of HFSA as part of Conda's scheduled plant turnaround during 2022. Following completion of the modifications and turnaround, Conda returned to full production capacity and began production of HFSA. Conda has also completed its first commercial delivery of the new product under a long-term offtake agreement.

"We are pleased to have safely and successfully completed our HFSA plant at Conda and look forward to supplying the North American market for many years to come. Our team did an incredible job to bring this initiative from concept to production in 18 months," said G. David Delaney, CEO of Itafos.

Elessent increases catalyst prices

Elessent Clean Technologies has announced an additional global price increase of $0.60/litre for its MECS® sulphuric acid catalyst products, effective immediately. The company says that additional surcharges may apply for freight, near term delivery and specialty product grades.

JORDAN

JPMC signs offtake agreement with Coromandel Fertiliser

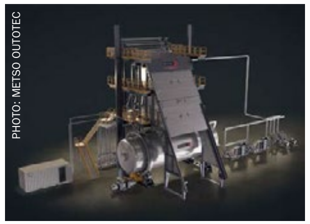
Jordan Phosphate Mines Company (JPMC) has signed an agreement to supply India's Coromandel Fertiliser Company with 100,000 tonnes of phosphoric acid up to the end of December. The agreement was signed in the UAE by JPMC CEO Abdulwahab Rawad and Coromandel's managing director in the presence of JPMC Chairman Muhammad Thnaibat. Thnaibat said that the agreement added to JPMC's record of agreements with a number of international companies, enhancing its competitiveness and global presence. He added that the agreement also lays the groundwork for a long-term partnership with Coromandel by supplying it with phosphoric acid produced by the Indo-Jordan Chemicals Company, which is fully owned by the JPMC. JPMC will also sign an agreement with Coromandel to supply it with Jordanian raw phosphate and DAP fertilizer until the fourth quarter of 2022 and in 2023.

JPMC has also signed a memorandum of understanding with the Munir Sukhtian Trading Group to establish a purified phosphoric acid plant at the port city of Aqaba, to produce 20,000 t/a of technical grade acid for the food industry. JMPC's Chairman, Mohammad Thneibat, said that the agreement would have a "positive and significant" impact on Jordan's food industry sector.

FINLAND

Modular converter hood for gas capture in smelting plants

Metso Outotec has launched a modular converter hood system for horizontal converter vessels used in the smelting process. The new system, which is suitable for both greenfield and brownfield installations, has a sulphur dioxide capability of 99%, minimising the environmental impact of the smelter. The company says that the modular design enables quick on-site assembly, minimising plant downtime. It also offers improved safety in the converter aisle; controlled ingress air flow for improved process gas quality; prolonged equipment lifetime due to the advanced water-cooling system; reliable operation with low maintenance needs; and expert service and support during commissioning as well as training for operators and management.



Outotec's new converter hood.

AUSTRALIA

Contract awarded for rare earths project

Australian Strategic Materials Ltd (ASM) has awarded Hyundai Engineering the contract to provide engineering, procurement and construction definition work for the Dubbo mining and processing project. Dubbo is a potential long-term resource of rare earths, zirconium, niobium, and hafnium located in New South Wales. At full capacity, the Dubbo plant will be capable of processing 1 million t/a of crushed ore via sulphuric acid leach and solvent extraction recovery. Mining will take place in a single open pit, then transported to the processing facility. Sulphuric acid used for leaching will be produced on-site using a sulphur burning acid plant that also generates electricity and steam for the process plant. A small amount of waste rock will be extracted and transported to a small waste rock emplacement (WRE) to the southwest of the open cut. The liquid and solid residues from the processing plant will be transported and stored in liquid residue storage facilities, solid residue storage facilities and salt encapsulation cells.

The contract includes a capital cost estimate), an operating cost estimate, a detailed project schedule, major project plans, and early-stage engineering documentation. Completion will allow Hyundai to produce an open book cost estimate for the project which will form the basis of an EPC offer to deliver the Dubbo project. Completion time is 14 months.

SOUTH AFRICA

Rare earths extraction from phosphoric acid production

Rainbow Rare Earths says that it has entered into a memorandum of understanding with an unspecified chemicals group based in South Africa to investigate the opportunity of extracting rare earth elements from a nitrophosphate process stream at its phosphoric acid production plant near Johannesburg. Under the terms of the MoU, Rainbow will conduct a rare earths extraction pilot study with the group, which will involve initial grade test work on processing stream material. This will be followed by a technical programme to confirm a flowsheet using Rainbow's knowledge and intellectual property gained from work carried out to date at the company's Phalaborwa Rare Earths Project in South Africa, including the licenced K-Technologies, Inc. separation technology.

The feedstock for the phosphoric acid plant originates from the same ore originally mined by Foskor that generated the two gypsum stacks at Phalaborwa. Rainbow says it has already completed preliminary sampling of the processing stream, with initial results indicating a total rare earth oxide grade of 0.81%, with a 27% weighting to high-value neodymium and praseodymium, alongside economic levels of terbium and dysprosium, similar to Phalaborwa. Direct costs associated with the pilot study conducted by Rainbow using its exclusive IP and technology will be financed by the chemicals group. Subject to a successful outcome, the parties intend to negotiate terms for a potential joint venture agreement to extract value from the rare earths present in the phosphoric acid processing stream.

Rainbow Rare Earths CEO, George Bennett, commented: "This project allows us to partner with a global chemicals business and demonstrates the significance and broader application of our IP and technology at another project in South Africa. This is a very exciting opportunity for Rainbow to release additional value from a nitro phosphate processing stream by efficiently producing separated rare earths, which are currently untapped within the phosphoric acid production process. As at our Phalaborwa Project, the rare earths in this stream are contained within an acid solution in a 'cracked form', which will allow us to apply the rare earths separation technology, thereby facilitating a simple process with significantly fewer extraction and separation steps than a traditional rare earth mining project. Through our processing projects, which have fundamentally different risk profiles to traditional rare earth mining projects, we see enormous potential to facilitate near-term access to sources of critical permanent magnet rare earths, which are required to decarbonise energy systems in an environmentally responsible way." ■

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Clariant has announced a reorganisation into three global business units instead of the previous five, with the business unit presidents to be located in the regions with the largest customer base and highest growth potential for the respective businesses. It will also create a new executive steering committee that will include the CEO, the CFO and the presidents of the new business units. The company says that the new structure aims to reduce hierarchical layers, foster greater accountability, speed up decision-making processes and enhance customer proximity, while strengthening diversity.

"With our new operating model and cultural transformation, we will foster better customer orientation, greater empowerment, accountability and transparency and take a new approach to leadership development promoting an inclusive and diverse culture – thereby securing Clariant's position to achieve its 2025 targets, in line with our purpose-led strategy," said Conrad Keijzer, Clariant's Chief Executive Officer.

Clariant will combine its existing Catalysts business unit and its Biofuels & Derivatives business line into a single business unit called "Catalysts". Functional Minerals and Additives will become "Adsorbents & Additives", and Industrial and Consumer Specialties and Oil and Mining Services will form the "Care Chemicals" business unit. The new units will be headed by newly appointed business unit Presidents **Angela Cackovich**, **Jens Cuntze**, and **Christian Vang**.

Angela Cackovich will become President, Adsorbents & Additives and the Europe, Middle East and Africa region. She will join Clariant's Executive Steering Committee from Tesa, where she was a member of the Executive Committee. She gained significant industry experience in several positions, including at Henkel, Celanese, Rohm & Haas as well as Dow Corning and Hoechst. As a German citizen she holds a master's degree in chemical engineering.

Jens Cuntze has extensive experience within the company. He will become President, of the Catalysts business unit, located in the Asia-Pacific region. Previously, he was Head of Corporate Planning & Strategy after serving in various leadership roles including Head of Petrochemical Catalysts and Head of Procurement. He holds a diploma and PhD in Chemistry from ETH Zurich and is German.

Christian Vang will become President of the Care Chemicals unit and the Americas region. He has more than 14 years of leadership experience within Clariant. His most recent positions included Head of Industrial and Consumer Specialties and Head of Corporate Planning & Strategy. Prior to joining Clariant in 2008, Christian worked in leading positions at Siegwerk, SICPA and Hempel. He holds degrees from Harvard, Insead and London Business School, and is a Danish national.

With the elimination of the Chief Transformation Officer (CTO) and Chief Operating Officer (COO) roles, the new structure enables direct reporting lines of Clariant's BUs to the CEO. As a consequence of the new structure, **Hans Bohnen**, Chief Operating Officer, and **Bernd Hoegemann**, Chief Transformation Officer, have decided to step down from their current roles in the Executive Committee and will pursue their careers outside the company.

Clariant will ensure additional transparency and accountability by moving away from its current structure of an Executive Committee with a sole oversight and review role. Instead, the Company will have a new Executive Steering Committee that will include CEO Conrad Keijzer, CFO Bill Collins as well as the three BU Presidents effective July 1st, 2022. Together with Chief Human Resources Officer Tatiana Berardinelli, General Counsel Alfred Muench, newly appointed Chief Corporate Development Officer Chris Hansen, and Chief Technology & Sustainability Officer Richard Haldimann, the Executive Steering Committee will form the Executive Leadership Team.

In terms of gender equality, Clariant says that it strives to provide equal opportunities for all genders with a special focus on strengthening the gender balance at the management level by doubling the current female representation to at least 30% by 2030.

Calendar 2022

! The following events may be subject to postponement or cancellation due to the global coronavirus pandemic. Please check the status of individual events with organisers.

JULY

29
ASRL Chalk Talk, CALGARY, Alberta, Canada
Contact: Alberta Sulphur Research Ltd
Tel: +1 403 220 5346
Email: asrinfo@ucalgary.ca

SEPTEMBER

12-16
Amine Experts' Amine Treating & Sour Water Stripping Technical Training Course, KANANASKIS, Alberta, Canada
Contact: Daniel Domanko, Senior Manager
Tel: +1 403 215 8400
Email: Daniel.Domanko@SulphurExperts.com
Web: AmineExperts.com

12-16
29th Annual Brimstone Sulfur Symposium, VAIL, Colorado, USA
Contact: Mike Anderson, Brimstone STS
Tel: +1 909 597 3249
Email: mike.anderson@brimstone-sts.com
Web: www.brimstone-sts.com

15-16
Oil Sands Conference & Trade Show, CALGARY, Alberta, Canada
Contact: Bruce Carew, EventWorx
Tel: +1 403 971 3227
Email: marketing@eventworx.ca

19-23
Sulphur Experts' Sulphur Recovery Technical Training Course, KANANASKIS, Alberta, Canada
Contact: Daniel Domanko, Senior Manager
Tel: +1 403 215 8400
Email: Daniel.Domanko@SulphurExperts.com
Web: AmineExperts.com

OCTOBER

9-13
XIII Round Table for Sulfuric Acid Plants, TEMUCO, Chile
Contact: Portus #1361, San Felipe, Valparaíso 2171881, Chile
Tel: +56 34 251 5557

10-14
Amine Experts Amine Treating Technical Training Course, NOORDWIJK, Netherlands
Contact: Jan Kiebert, Senior Manager
Tel: +31 71 408 8036
Email: Jan.Kiebert@SulphurExperts.com
Web: AmineExperts.com

17-21
Sulphur Experts Sulphur Recovery Technical Training Course, NOORDWIJK, Netherlands
Contact: Jan Kiebert, Senior Manager
Tel: +31 71 408 8036
Email: Jan.Kiebert@SulphurExperts.com
Web: SulphurExperts.com

19-23
Sulphur Experts' Sulphur Recovery Technical Training Course, KANANASKIS, Alberta, Canada
Contact: Daniel Domanko, Senior Manager
Tel: +1 403 215 8400
Email: Daniel.Domanko@SulphurExperts.com
Web: AmineExperts.com

Southern Africa's sulphur and acid mix

PHOTO: IVANHOE MINING

Copper leaching and smelting projects in Zambia and Zimbabwe continue to dominate acid production and consumption, with output expected to increase from the Kamoa-Kakula project.

Left: The Kamoa copper mine and processing facilities, DRC.

While north Africa's sulphur demand is dominated by its phosphate industry, in Morocco, Tunisia, Algeria and Egypt, south of the Sahara it is copper, cobalt and uranium mining, leaching and smelting that hold sway over acid production and demand, and hence sulphur requirements. As Figure 1 shows, much of this is concentrated in the 'Copper Belt' across central Zambia and the south of the Democratic Republic of Congo (DRC).

Sulphur

Regional sulphur production remains relatively small and mostly dependent upon refining, with the exception of sulphur recovered from coal and gas to liquids production at Sasol's plants at Secunda and PetroSA at Mossel Bay (although the latter has been shuttered for a few years due to lack of gas availability). But southern Africa's refining sector is small, and over the past few years has run at ever-lower production rates. As Table 1 shows, there are currently 21 refineries across the region, and in theory regional refining capacity is just over 1.5 million bbl/d. However, most of these are small and relatively simple refineries with low upgrading capacity built many years ago, and suffering from low refining margins, small local markets, high operating costs and poor yields, and a number of them are not currently operational. Ghana's Tema refinery has been offline since January 2017, when it was closed by an explosion at the site. Cameroon's Limbe refinery has likewise been shut down after a fire in 2019, and SAR in Senegal has been shut down since November 2021 for repairs. South Africa, home to the largest refineries, has seen all of them close progressively over the past three years. The Caltex/Chevron refinery in Cape Town was shut down after a fire in late 2020, although it has been bought by Glencore subsidiary Astron Energy, which says that it plans to reopen the refinery later this year. BP and Shell decided to stop operations indefinitely at the Sapref refinery in Durban, the country's largest with a capacity of 180,000 bbl/d, in March 2022, though they have not ruled out a sale or re-start. Engen, a unit of Malaysia's Petronas, has also shut down its 120,000 bbl/d refinery in South Africa following an explosion and fire in 2021, and says that it will convert it into an oil receiving terminal in 2023. Sasol and its joint venture partner Total are considering selling or closing the 107,000 b/d Natref refinery at Sasolburg.

At issue in South Africa has been pending clean fuel regulations which would have mandated a reduction to 10 ppm sulphur content of fuels. However, this would involve considerable investment at the country's ageing refineries, and although the start date for the regulations has been pushed back from 2017 to 2026, most of the operators in the country have concluded that it is cheaper to simply close capacity and import from overseas. Sasol is already having to spend $400 million to upgrade its Secunda CTL plant to meet clean fuel standards. It has been a similar story across the continent, with western oil majors withdrawing from refinery projects and local investors and governments not being able to invest sufficiently to plug the gap.

The upshot is that in spite of being responsible for 8% of the world's oil production, sub-Saharan Africa exports its crude production and imports refined products, with regional refinery operating rates down to just 30% in 2021. Even Nigeria and Angola, major oil producers, import 80% of their domestic fuel needs. As crude prices have soared this year because of the Ukraine conflict, this has left many countries short of fuel supplies, especially aviation fuel.

Some relief may be on the horizon. Africa's richest man, Aliko Dangote, is

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building a world-scale refinery in Nigeria that will have a capacity of 650,000 barrels a day. However, construction has been delayed by covid and other factors, and its start-up is not expected until 2023. Angola is also tendering for a 200,000 bbl/d refinery to be built by state oil company Sonangol. In spite of its size, the Dangote refinery will produce only 32,000 t/a of sulphur at capacity as Nigerian oil is relatively sweet and local fuel standards are fairly forgiving of sulphur content. At the moment, therefore, most sulphur in the region comes from Sasol's Secunda plant, with a capacity of 140,000 t/a. Even once new refinery capacity is taken into account, sub-Saharan sulphur output will remain very small compared to regional sulphur demand of around 2 million t/a.

Mining and metals

In spite of the lack of domestic sulphur production, there is a sizeable sulphuric acid industry in the region, mostly for metals processing, and sulphur demand has been increasing steadily as a result. The US Geological Survey estimates that world cobalt production was 170,000 t/a in 2021, of which 120,000 t/a, or 70%, was entirely due to the Democratic Republic of Congo (DRC). Meanwhile South Africa and Zimbabwe produce 80% of the world's platinum, and Zambia and the DRC mine 13% of the world's copper. China's rapid industrialisation has led to a rapidly growing appetite for raw materials of all kinds, and the country's need for copper has generated a great deal of investment in Africa's Copper Belt. Recent investment has focused upon the increasingly important cobalt industry – cobalt tends to be co-produced with copper. Cobalt is used in batteries and the spread of electric vehicle use worldwide has led to increased demand for the metal. Other acid consuming industries include uranium and zinc mining as well as phosphates. Sulphur and sulphuric acid production and use is however dominated by just four countries; Zambia, the DRC, South Africa and Namibia.

Zambia

Zambia has historically been the region's major copper producer, though its copper production has been overtaken in the past decade by the DRC. The country was also the first to build copper smelter capacity, some of it dating back to the 1930s. The first smelter in the country was the Nkana smelter at Kitwe, first commissioned in 1931, with a capacity of 6,000 t/a, expanded to 330,000 t/a by the 1970s, but down to 165,000 t/a by the 2000s. The Nkana smelter, then operated by Konkola Copper Mines, a subsidiary of Vedanta, was finally closed in 2009. Its replacement was the Nchanga smelter at Chingola, using an Outotec direct-to-blister design. The smelter was commissioned in 2008 to replace Nkana, and has a nominal capacity of 300,000 t/a of copper and 1.0 million t/a of acid. Nchanga has been shut down since 2019, however, owing to legal disputes over sulphur dioxide emissions and alleged breaches of license conditions and unpaid tax in a government attempt to gain control of the resource. The government has sought to sell the smelter to a new investor, something which Vedanta has described as "illegal", and the company says it awaits the result of arbitration hearings due for January 2023 in London.

Fig. 1: **Sub-Saharan Africa's sulphur production and consumption**

Mopani Copper Mines commissioned their IsaSmelt plant at Mufulira in 2006. It was designed to initially smelt 650,000 t/a of concentrate, and replaced a previous 1970s vintage electric smelting furnace, which in turn had replaced the original 1937 reverberatory furnaces. The smelter was originally owned by a consortium including First Quantum Minerals, ZCCM-IH, and Glencore, though Glencore sold its stake to ZCCM-IH in 2021 for $1.5 billion, and the company is now in the middle of a financial restructuring. Copper production is around 185,000 t/a.

China Nonferrous Metal Mining Group began operations at its Chambishi copper smelter at the end of 2008. The IsaSmelt smelter was initially designed to produce 150,000 t/a of blister copper, later expanded to 300,000 t/a. Sulphuric acid capacity is 360,000 t/a.

Finally, the Kansanshi copper smelter began operations at Solwezi in 2015. It uses IsaSmelt smelting technology, and has an output at capacity of 300,000 t/a of blister copper (actual production was 202,000 tonnes in 2021). Kansanshi Mining is 80% owned by Vancouver-based First Quantum Minerals Ltd and 20% owned by Zambian mining parastatal Zambia Consolidated Copper Mines Investment Holding (ZCCM-IH). Sulphuric acid capacity is 1.3 million t/a.

In addition to the four copper smelters, Zambia also has several solvent extraction/electrowinning copper leach operations. The Chingola tailings leach plant, developed in the mid-1970s, was actually the first large scale SX/EW operation in the world. First Quantum operated the Bwana Mkubwa plant from 1998-2010, while Mopani Copper Mines has four SX/EW plants, two at Mufulira and two at Nkana. Kansanshi also produces SX/EW copper, requiring up to 1.0 million t/a of sulphuric acid from the smelter.

The previous Zambian government, led by Edgar Lungu, had made Zambia a difficult investment environment with the government using the mining companies for cash grabs, including at one stage a tripling of royalty payments on mines and allegations of unpaid taxes such as at KCM, stalling the development of the country's copper and cobalt industry. However, the election of Hakainde Hichilema as president last year seems to be turning that around, and he has unveiled plans to boost copper output from the current 800,000 t/a, where it has been for over a decade, to more than 3 million t/a in 10 years. Some industry observers have called this an "inflection point" in African copper mining.

DRC

The copper industry in the Democratic Republic of Congo developed later than that in neighbouring Zambia. There is a small smelter at Likasi, in Katanga province run by Indian company Rubamin, with a capacity of 20,000 t/a of blister copper from malachite ore, and more recently a much larger Chinese-funded smelter at Lualuba which can produce 120,000 t/a of copper and generate 240,000 t/a of acid. But much of the country's copper industry has been built on the back of cheaper copper leaching capacity via SX/EW. This is aided by higher grades of copper ores in the DRC – over 3-5% Cu content, compared to 0.6-0.8% in most other places. The need for sulphuric acid to operate DRC's leaching plants was initially fed by surplus acid from the Zambian smelters, allowing the two countries to operate symbiotically for several years. Zambia produced around 1.0 million t/a of acid in excess of its 2 million t/a requirements and exported it to the DRC, and in return took copper concentrate from the DRC to use in its smelters. However, Zambia raised import taxes on copper concentrates in 2018, leading in part to the shutdown of the Nchanga smelter, and the loss of its acid supply to the DRC.

In spite of this, DRC copper production has continued to increase, reaching 1.8 million t/a last year. The largest SX/EW operation is Tenke Fungurume Mining (TFM), originally developed by Freeport McMoRan, but sold to China Molybdenum in May 2016, and now the subject of a dispute between China Moly, which owns an 80% stake, and the government over declaration of reserves. Two other major SX/EW operations are the Glencore-owned Kamoto Copper Company (KCC) and Mutanda Mining, both located near Kolwezi.

To produce enough acid to feed this production there are now several sulphur burning acid plants in operation in the DRC, including a 300 t/d plant at Sicomines, a 200 t/d plant at Gecamines, and an 825 t/d and a more recent 1,400 t/d plant at Tenke Fungurume. China's Huyaou Dongfang has a 4,000 t/d plant and Shalina Resources has 600 t/d of capacity in two plants. There is also a small 33 t/d plant at Kambove. All of this, added to the smelter capacity, takes DRC acid production to nearly 4 million t/a, and now construction has begun on a new 500,000 t/a direct-to-blister flash smelter at Ivanhoe Mines' Kamoa-Kakula copper mining complex. Kamoa-Kakula generates 200,000 t/a of copper in Phase 1 (already operational), with an expansion to 400,000 t/a in Phase 1. The company says that the Phase 3 expansion will make the mine the third largest copper producer globally, increasing copper production capacity to about 600,000 t/a by 4Q 2024, and eventually to 800,000 t/a. Kakula is projected to be the world's highest grade major copper mine, with an initial mining rate of 3.8 million t/a at an estimated average feed grade of more than 6.0% copper over the first five years of operations.

The consequence of this flurry of activity is that the DRC's reliance on imported acid is likely to decline, potentially leading to problems for Zambia's producers in respect of disposal of excess acid. This has been masked over the past couple of years by the shutdown of the Nchanga smelter in Zambia and operating disruptions caused by covid, but could become a more pressing issue as production ramps back up again.

Namibia

Namibia is home to the region's main uranium mining activities. After years of a depressed global market for uranium, China's requirements for uranium for civilian nuclear power have led to Chinese companies moving into take over and expand Namibia's two major uranium mines. The China National Uranium Corporation (CNBC) bought the Roessing mine from Rio Tinto, while CGN-Uranium Resources Co bought the Husab mine. Roessing takes

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Table 1: **Refineries in sub-Saharan Africa**

Country	Location	Operator	Capacity ('000 bbl/d)
Angola	Luanda	Sonangol	65
	Lobito	**Sonangol**	**200**
Cameroon	*Cape Limboh Limbe*	*Societe Nationale*	*70*
Chad	Ndjamena	CNPC	20
Congo	Pointe Noire	Coraf	21
Gabon	Port Gentil	St. Gabonaise	24
Ghana	*Tema*	*Tema Oil*	*45*
Ivory Coast	Abidjan	Societe Ivoirienne	84
Liberia	Monrovia	Liberia Petroleum	15
Niger	Zinder, Ganaram	CNPC	20
Nigeria	Kaduna	NNPC	110
	Port Harcourt	NNPC	210
	Warri	NNPC	125
	Lekki	**Dangote**	**650**
Senegal	*M'Bao (Dakar)*	*St Africaine*	*25*
Sierra Leone	Freetown	SLPRC	5
South Africa	*Cape Town*	*Astron Energy*	*110*
	Durban	*Engen (Petronas)*	*150*
	Durban	*Shell/BP*	*180*
	Sasolburg	*NPRSA (Sasol/Total)*	*105*
Sudan	Khartoum	CNPC	100
	Port Sudan	Sudan Government	47
Zambia	Bwana Nkubwa Area	Zambia Government	12

Note: Entries in italics are not currently operational. Entries in bold are under construction or development.
Source: McKinsey, Reuters

sulphuric acid from the Tsumeb metal smelter to dissolve uranium ores, occasionally buying import tonnages via Walvis Bay. At peak production consumption is up to 260,000 t/a of sulphuric acid, although it is typically lower. Huseb has its own dedicated 1,500 t/d sulphuric acid plant.

Namibia's other sulphuric acid plants are operated by Vedanta Zinc, which runs the Skorpion Zinc mine and NamZinc processing facility, and Dundee Precious Metals, which runs the Tsumeb copper smelter. NamZinc is a unique zinc SX/EW facility with its own dedicated sulphur-burning acid plant with a capacity of 1,150 t/d. Meanwhile the Tsumeb smelter, which started up in 1963, commissioned a 400,000 t/a sulphuric acid plant in 2015 to deal with SO_2 emissions from the smelter, under the auspices of Dundee Precious Metals, who bought the site in 2010 and increased production by 60%.

South Africa

South Africa has a single major copper smelter: Palabora Copper in the Limpopo Province has been operating since 1966, and currently produces around 60,000 t/a of copper and 180,000 t/a of acid. The two zinc smelters in the country have been mothballed, but there is also some acid coming from processing of platinum group metals at a number of sites. However, sulphuric acid capacity in South Africa is mainly dominated by phosphate fertilizer production. DAP and phosphoric acid producer Foskor buys in acid from local smelters as well as operating 2.2 million t/a of sulphur burning acid capacity in three large trains at Richards Bay. Sasol also produces sulphuric acid at its Secunda CTL plant. Foskor took sulphur from local refineries, but with them shut down has had to turn to imports of sulphur. South Africa also used to sell excess sulphuric acid to the DRC's copper leaching plants, but with acid capacity increasing there, there are questions as to where excess South African acid will go to.

Other consumers

Senegal imports around 3-400,000 t/a of sulphur to generate acid for its phosphate production at Industries Chimique du Senegal, owned by Indorama. There is also the Ambatovy high pressure acid leach nickel facility on Madagascar, with 60,000 t/a of nickel capacity, which requires up to 500,000 t/a of sulphur, though it has rarely run at more than $^2/_3$ capacity. Ambatovy was shut down for a year from 2020-21, and its operating losses have led to a debt restructuring that saw Sheritt reduce its stake and its Korean state-backed investors to consider pulling out, though recent indications were that the government has had a re-think on this for now. Sumitomo retains the largest stake in Ambatovy for now.

Uganda has a large copper mine in the west of the country at Kilembe which is estimated to contain about 4 million tonnes of 2% copper and 0.17% cobalt ore, but which has not operated since the 1980s and the demise of the domestic copper smelter. The government is now said to be keen to rehabilitate it to boost domestic industry and has asked for expressions of interest.

Finally Chinese investors have become very interested in Zimbabwe's deposits of lithium. Zhejiang Huayou Cobalt is planning to invest $300 million into its Arcadia lithium mine near Harare, and construct a plant with a processing capacity of 4.5 million t/a of ore and a production capacity of 40,000 t/a of lithium concentrate. Shenzhen Chengxin Lithium Group and Sinomine Resource Group have also invested in Zimbabwe's lithium mines with an eye on battery production for electric vehicles. The Zimbabwean government is pushing for domestic lithium carbonate production, which would require 2.2 tonnes of sulphuric acid per tonne of lithium.

Infrastructure issues

One of the major issues that the region faces is lack of transport infrastructure, which can lead to long lead times for sulphur or acid transport and high end user prices. Sulphur has to be brought in from out of the region via ports at Dar es Salaam in Tanzania, Beira in Mozambique, Richard's Bay near Durban in South Africa, Walvis Bay in Namibia, and Lobito in Angola. However, as Figure 1 shows, these are 1,600-3,000 km from the copper belt along poor roads and crossing several borders, often involving long queues and bureaucracy, tolls and bandits. Even so, taking sulphur on an outward trip and copper cathode or cobalt hydroxide on the return is proving to be a profitable operation for regional trucking companies. The DRC alone now imports over 500,000 t/a of sulphur. And with the world's appetite for copper seemingly endless and copper demand projected to rise from 21 million t/a to 25.5 million t/a by 2030, leading to a potential shortfall of up to 6 million t/a from existing projects, it seems likely that Africa will be seeing more acid production and more sulphur demand over the coming years. ■

PHOTO: KGHM

Trends in base metal smelter acid production

Acid output is expected to increase as copper mining and smelting increases; the copper market is moving moves from deficit to surplus, with copper output expected to rise 5% in 2022 as demand increases for electric vehicles.

Above: The Glogow copper smelter in Poland.

Base metal smelting makes up about 30% of the world's production of sulphuric acid. Because it is involuntary production to avoid emissions of harmful sulphur dioxide, production of smelter acid is driven primarily by the economics of metal markets rather than sulphuric acid prices, and hence it is often produced regardless of prevailing acid market conditions. And while sulphur-burning acid capacity is usually integrated into local downstream uses, especially phosphate fertilizer production, but also copper and nickel leaching etc, this is far less frequently the case for smelter acid production. Domestically and internationally traded acid thus tends to come mainly from smelter acid.

Acid from metal smelting is predominantly (about 70%) generated by the copper industry, with zinc and lead smelting representing approximately another 20% of production and the rest mainly from nickel. These base metal industries are destined primarily for construction and industrial end uses and their consumption is closely tied into general economic and industrial growth.

Copper

Copper demand is mostly for electrical wiring, industrial machinery, electronic products, transportation and similar fields, and so is closely correlated with industrial production. Most incremental demand over the past 20 years has come from China's industrialisation, to the extent that, of world copper consumption of 25.6 million t/a in 2021, North America represented about 9% of this demand, the EU 11%, but China 56% and the rest of Asia about 18% (see Table 1). China's rate of economic growth peaked in 2007 at over 14%, slowly falling to 6% by 2019 due to demographic changes and a transition from an industrial to a consumer led economy. Covid lockdowns crimped growth to 2.2% in 2020, rebounding to 8.1% last year, but this year is forecast to be 4-5%, as covid, energy prices and economic uncertainty continue to impact upon the global economy. Copper demand from China's property market, which accounts for about 9% of global copper consumption, is struggling very badly due to oversupply. Overall,

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Table 1: **Global refined copper supply-demand balance, 2021 (million t/a)**

Region	Production	Consumption
China	10.6	14.5
Americas	4.4	1.8
Europe	3.7	2.9
Others	6.2	6.5
Total	25.0	25.6

Source: ICSG

Chinese apparent copper demand will be up by about 5.2% in 2022, following a flat year in 2021 when the stocks that were built up in 2020 were worked down.

Outside of China copper demand is mixed. US copper demand could grow by 7% in 2022, whereas Europe has been hit hardest by the consequences of the war in Ukraine and copper demand could contract by 2-3% due to high energy costs.

Supply is relatively balanced, and the war in Ukraine has not affected copper prices as much as many other commodities. Russia represents only 4% of world copper supply. The International Copper Study Group (ICSG) forecasts that the copper market will be in slight deficit this year (about 475,000 tonnes) which should also support higher prices, but after that a surplus is likely over the next few years, with prices falling towards $8,000/tonne, before moving back up in about 2025.

Looking further ahead, copper will be in demand for the continuing electrification of vehicle and other markets. Rio Tinto estimates that by 2050, over 25% of copper consumption will be attributable to the additional demand associated to the transition to net zero emissions. Increasing use of electric vehicles has already started to make an impact on copper demand; EVs use around four times as much copper as conventional vehicles, including batteries, windings and copper rotors used in electric motors, wiring, busbars and also associated charging infrastructure.

> **"Increasing use of electric vehicles has already started to make an impact on copper demand."**

The copper market continues to be supplied mainly by smelting of copper concentrate, accounting for around 70% of all copper production according to ICSG figures. Copper leaching via solvent extraction/electrowinning accounts for another 16% and secondary refining (recycling of scrap copper) about 14%. While SX/EW capacity had risen rapidly over the first two decades of the 21st century, growth has now slowed, and new copper capacity is often based on concentrate smelting. About two thirds of all copper smelting now occurs in Asia, with China again responsible for the lion's share.

Nickel

Nickel is, like copper, closely tied to industrial growth. Just over two thirds of all nickel (70%) is used in the manufacture of stainless steel, and the rest goes into other alloys (8%), nickel plating (8%), casting (8%) and nickel-cadmium batteries (5%). As with copper, China has come to dominate the market, consuming 55% of all nickel in 2021, according to the International Nickel Study Group (INSG). Nickel demand has been boosted by its use in electric vehicle batteries, and is expected to grow by 3.7% year on year over the next five years from 2.9 million t/a to 3.4 million t/a in 2027.

Historically, most nickel production came from sulphate ores which required smelting and generated sulphur dioxide and hence sulphuric acid. While the market for nickel is much smaller than copper (around 3 million t/a as opposed to 25 million t/a), nickel ore grades are lower, so smelting can generate more sulphur per tonne of metal than it does for copper. But a shortage of available sulphate ores – only around 30% of nickel is found as sulphate - has led to greater concentration on cheaper, lower grade laterite (oxide) ores, which are processed either via pyrometallurgical routes to generate ferronickel or so-called nickel pig iron (NPI), or via acid leaching routes, particularly high pressure acid leaching, or HPAL. Thus, while there are still some prominent nickel smelting operations around the world, such as Norilsk Nickel, Boliden at Harjavalta in Finland, and Jinchuan Non-ferrous Metals in Jinchang, China, new nickel smelting operations are few and far between, and new nickel capacity tends to be an acid consumer rather than producer.

Zinc and lead

Zinc and lead production produce the remainder of the world's smelter acid. Global lead demand is expected to be about 12.4 million t/a in 2022, according to the International Lead-Zinc Study Group (ILZSG). Zinc consumption is projected to be 14.3 million t/a this year. However, lead has a much higher rate of recycling, from e.g. old lead-acid car batteries, and actual lead mine production for smelting will be only about 4.7 million t/a in 2022, while zinc mine production will be about 13.3 million t/a.

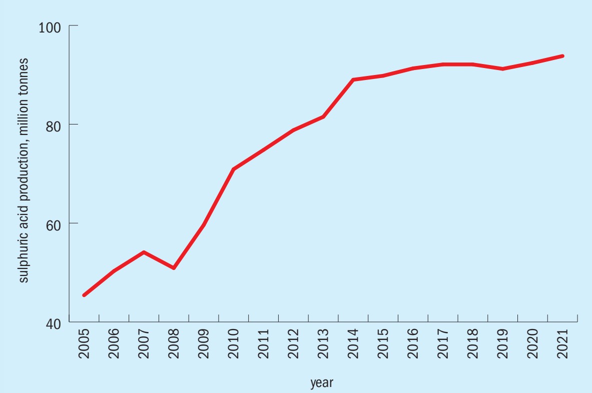
Batteries represent about 90% of all demand for lead, with electric scooters a particularly rapid growth area. However, lead-acid battery technology is old and it is gradually being replaced by lithium batteries in transport applications, meaning that demand for lead is set to plateau and slowly decline.

Zinc is mainly used in galvanising of steel (50%), and the manufacture of brass and bronze alloys and die casting, and is closely linked to construction and urbanisation. As with copper and nickel, China has driven world markets this decade, and represents around 40% of all consumption of lead and 35% of zinc demand. Chinese lead smelting produced about 2.7 million t/a of lead in 2021, or about 60% of all primary lead production. This is forecast to remain relatively constant over the next five years, with recycling becoming more important and lead acid batteries gradually replaced by lithium batteries.

China

China continues to be the most important country as far as metal demand is concerned, and it has expanded its domestic metal processing capacity considerably over the past two decades to feed this. Production of smelter acid in particular has increased rapidly. Figure 1 shows the growth in China's sulphuric acid industry, and much of the growth between 2005-2015 came from new smelter acid. Smelter acid now represents around 35% of China's 129 million t/a of acid capacity, with sulphur-burning plants, mostly for phosphate and titanium dioxide production, around 46% and pyrites 16.5%. But lower operating rates for pyrite and sulphur burning capacity means that smelter acid actually represents a higher share of total production. Geographically, eastern China has the majority of sulphuric acid capacity, particularly in Anhui, Jiangxi and Shandong provinces, including major smelters such as Anhui Tongling Nonferrous Metals (4.6 million tons/year), Jiangxi Copper (3.2 million tons/year), Shandong Yanggu Xiangguang (1.7 million tons/year).

Fig. 1: **China's sulphuric acid production, million tonnes/year**



Source: National Bureau of Statistics of China

On top of this, a further 9.3 million t/a of new acid capacity is forecast to be completed in 2022, including 3 million t/a of smelter acid capacity, and over the next five years this expansion could reach 21 million t/a of total acid capacity. However, Chinese authorities have begun to crack down on energy-intensive industries as part of the country's aim to reduce its carbon emissions. The China Non-Ferrous Metals Industry Association (CNIA) has set a provisional goal of bringing non-ferrous metal carbon emissions to a peak by 2025 and cutting them by 40% by 2040. China aims to reach peak overall emissions before 2030 and to become carbon neutral by 2060. New standards for scrap recycling will allow greater reuse of copper and reduce condensate imports. On the lead side, tougher environmental regulation has also led to the shutdown of a number of lead smelters, with nine closing from 2015-2020, representing 0.6 million t/a of lead production, or almost 20%. Zinc production too is highly energy intensive and faces cutbacks. Thus although China will be a net acid exporter over the next few years, possibly reaching as much as 3 million t/a in 2022, Chinese smelter acid capacity is expected to peak in 2025 and acid output from smelting fall thereafter.

Asia

Asia ex-China represents the bulk of remaining smelter capacity, with Japan, South Korea and India all operating several large units. However, the prospects for new production in these countries are limited, and the shutdown of the Sterlite copper smelter in India has removed around 1.2 million t/a of acid capacity, though operator Vedanta still has plans to build a new smelter to replace it. Outside of these countries, new smelter capacity in Asia is concentrated in Indonesia, where the government has tried to ban the export of copper and nickel ores and copper concentrates and force the development of a downstream metal processing industry to capture more of the value chain. PT Smelting, a joint venture between Mitsubishi Materials Corp and Freeport Indonesia, is currently expanding its East Java copper smelting facility from 300,000 t/a to 342,000 t/a of copper cathode by the end of December 2023, while Freeport and Chiyoda began construction of a new $3 billion copper smelter at Gresik on East Java last year, with a projected capacity of 600,000 t/a of copper, making it the largest single train smelter in the world. It is due for completion in 2025 and will take concentrate supplied by PT Freeport Indonesia's Grasberg mine in Papua. Indonesia also expects to complete a lead and a zinc smelter this year, as well as numerous ferronickel units.

Elsewhere

Africa's Democratic Republic of Congo is seeing a new copper smelter being constructed at Ivanhoe Mines' Kamoa-Kakula copper mining complex. The smelter will produce 500,000 t/a of copper at capacity, and is scheduled to open in 2025. Vedanta is also looking to build a new zinc smelter at its Gamsberg zinc mine, near Aggeneys, in South Africa. The project would produce 300 000 t/a of high-grade zinc by processing 680 000 t/a of zinc concentrate, generating 450,000 t/a of sulphuric acid for both export and consumption within South Africa.

In Europe, Swedish mining firm Boliden has decided to increase zinc production at the Odda smelter in Norway with an investment of $825 million to almost double annual zinc capacity from 200,000 t/a to 350,000 t/a. As part of the expansion plan, the firm will build several new facilities at the site, including a new roaster, sulphuric acid plant and cellhouse. At the same time, high energy prices are forcing closures of smelters in Europe – Nyrstar placed its Auby zinc smelter in France on care and maintenance in January due to high electricity prices, and Glencore closed its Portovesme zinc plant, collectively removing 260,000 t/a of zinc capacity.

Activity is much more muted in South America, where the Peruvian government has shelved the controversial Tia Maria copper project and Chile's Codelco has tried but failed to close its Ventanas smelter, settling instead for new environmental improvements. Chile still aims to build more copper smelting capacity to add value to its copper production, and Enami has proposed to double capacity at its Hernán Videla Lira copper smelter in Paipote to 1.4 million t/a of concentrates by 2026, generating 200,000 t/a of copper cathode. ■

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Sulphur World Symposium 2022

The port of Tampa.

PHOTO: ALAMY

The Sulphur Institute's (TSI's) annual Sulphur World Symposium was held in Tampa, Florida this year, from May 9th-11th.

After the cancellation of the 2020 Sulphur World Symposium due to the covid-19 outbreak and last year's virtual conference, it was a welcome return to a face to face meeting for the 2022 event. Held at Tampa, one of the major ports for import of sulphur into the US, the Symposium began with a waterside tour of industry facilities in the Tampa Bay region, covering both liquid and dry bulk import and export terminals that support the sulphur, sulphuric acid, and fertilizer supply chains.

Global economic outlook

As is traditional the Symposium proper began the next morning with a roundup of the global economic outlook, this time presented by Dr. Georgy Egorov, professor of Managerial Economics & Decision Sciences at the Kellogg School of Management. He reviewed the disruptions of the past two years, with the covid outbreak leading to a major recession, driven by both demand and supply disruptions which were larger than expected. However, remote working, vaccines and major financial assistance programmes in developed countries have finally led to a rapid rebound in demand that supply chains have yet to catch up with. The Ukraine war on top of all of this has compounded supply issues and led to commodity prices spiking to levels not seen for more than a decade. There has also been an upswing in populism and anti-globalism and, Georgy argued, a distrust or antipathy to global institutions which have not been able to tackle the crises. Overall world economic growth is now forecast to drop from 6.1% in 2021 to 3.6% this year and next, with developed economies averaging 3.3% and 2.4% in 2022 and 2023, and emerging markets 3.8% this year and 4.4% next. Growth remains strongest in developing Asia, followed by sub-Saharan Africa. Georgy also pointed out that growth has returned in international trade in goods, but not services. High prices are fuelling inflation, and expectations of inflation, leading to tight money and a risk of recession in G20 countries. The outlook remains uncertain because of the Ukraine situation, with a real risk of a food crisis in the Middle East and energy crisis in Europe. Over the longer term, Georgy forecast a more fragmented world, with reshoring of companies and uncertainty over the future of the EU, WTO and China.

Dry bulk freight markets

Brian Malone of MID-SHIP Group looked at freight markets, all of which are at high values, though not as high as 3Q 2021. Year on year, the Baltic Index is up less than 2% for most ship classes, except for a 10% hike in Capesize markets. Freight rates are forecast to peak over the next three months before falling back from October onwards. There is a relatively fine balance between vessel supply and demand, but bullish sentiment in commodity and fuel markets, coupled with inflation and rising interest rates. High sulphur fuel oil is trading at a $110-180/t discount to low sulphur fuel oil, for those who are able to operate fuel scrubbers.

Global energy outlook

The global energy outlook was presented by Thomas Miller of BP Energy. He looked ahead at energy demand in 2050 according to three scenarios; New Momentum, representing the current broad trajectory of the global energy economy, including an increasing focus on decarbonisation; Accelerated; and Net Zero, which explore how different elements of the energy system might change in order to achieve a substantial reduction in carbon emissions. New Momentum would see a rise of 10-15% in global energy consumption out to 2050, Accelerated a reduction of a similar magnitude, but achieving Net Zero would take a 25% reduction in energy use over today. Even New Momentum would see a decrease in use of fossil fuel use of 25% by 2050 compared to today, however, with oil consumption dropping to 80 million bbl/d, with Net Zero a 75% fall. Gas demand would rise under New Momentum to 5 tcm per year, with power generation taking the largest slice of this, but fall sharply under the other two scenarios, which would require much greater investment in renewable energy. There followed a discussion on carbon credits led by Jeff Cole of Shell Emerging Energy Solutions.

Sulphur enhanced fertilizers

Dr Hunter Frame, an agronomist form Virginia Tech University, looked at sulphur's role in the environment, especially as regards crop nutrition. Taking the whole of North America as his starting point, he pointed out that while reducing sulphur burning in fuels or scrubbing coal power station stack emissions has reduced sulphur deposition in the industrial midwest, for much of the country little has changed. This has led to an increased consumption for sulphur containing fertilizers, particularly for sulphur hungry crops like peanuts and sugarcane. However, concerns about the effect of sulphate on soil health and leaching into water courses do not seem to be borne out by evidence. Indeed, soil sulphur levels appear to continue to fall. The behaviour of sulphate in the field can be difficult to model, as mineralisation rates are unpredictable, and sulphates can be held in deep clay layers and released slowly. Deep soil sampling can show surprisingly high sulphur levels, but this is not necessarily available to the plant.

Overall, he supported higher application rates for agricultural sulphur and greater use of sulphur enhanced fertilizers, pointing to the significant yield increases and benefits to plant health that it can bring.

Phosphate market

Mike Rahm, formerly of Mosaic but now operating his own consultancy, presented the phosphate market outlook. He noted how we seemed to have entered a 'new normal', where prices of many commodities were now 2-3 times what the average price had been during 2015-19. In the case of phosphates, he discounted the idea that US duties on phosphate imports had much to do with current price levels, but rather a series of fundamental factors including strong demand driven by higher agricultural commodity prices and the need to increase crop production; a muted supply response to the price fly-up and a thin pipeline of projects; major changes in Chinese industrial, environmental and export policies; elevated raw materials costs due partly to the rapid transition to low-carbon energy (particularly in Europe); and of course disruptions caused by the Russia-Ukraine war.

Tackling these factors one by one, he highlighted Brazilian import demand, which has tripled in the past decade, and continuing strong demand from India. There is a need for increased crop production, and global stocks of grain and oilseed are below their usual range bounds, driving up crop prices. Conversely, supply build is relatively muted; US phosphoric acid production has actually declined by 25% over the past decade, and while Moroccan exports have increased, Russian exports (prior to the war) and Chinese exports had been flat. Indeed, recent Chinese restrictions on phosphate exports have led to a 58% drop in supply from China. Meanwhile, prices of key inputs such as sulphur and ammonia (for MAP/DAP production) are at very high levels, and in ammonia's case expected to remain so, increasing the base production cost of DAP by $450/t in two years. Ammonia availability could even limit Moroccan production this year, and Morocco has also historically sourced 10-20% of its sulphur requirements from Russia.

Overall, Mike expected phosphate process to remain higher for longer, absent any of three things; a resolution to the Ukraine conflict, an earlier than expected and larger return to the market for Chinese exports, or extreme demand destruction resulting from higher prices. Looking further forward, he saw a positive long-term outlook based on moderate demand growth, large capacity additions and higher operating rates. Requirements for renewable diesel fuel in the US could boost oilseed production and "do what ethanol did for corn fifteen years ago". Other fresh demand might come from lithium ion phosphate batteries for electric vehicles and Chinese feed grain demand. However, he pointed to declining grades of phosphate rocks and falling sulphur production as the world switches away from fossil fuels as potential issues for phosphate production in the longer term.

Sulphur and sulphuric acid

CRU's Peter Harrison ended the Symposium with the traditional round-up of sulphur and sulphuric acid markets. Sulphur prices were at a 14 year high, he said, though still below the record levels seen in 2008. The had begun rising in early 2021, driven by supply tightness and a rebound in demand, then run up further at the end of last year due to lower exports from the Middle East and Russia, before finally shooting up in 2Q 2022 because of the Ukraine conflict. Russia, Kazakhstan and Turkmenistan collectively represent 18% of the world's 34 million t/a of traded elemental sulphur, but dependence on these sources is much higher in some regions; 34% in Europe and 50% in Brazil. Russian exports had already been falling prior to 2022, and though buyers are still taking Russian sulphur, sanctions have impacted trade.

Acid prices are also elevated, though the rate of increase has slowed. Sulphur price increases have outpaced rises in consuming markets such as copper, nickel and phosphates, leading to demand destruction, and sulphur consumption is likely to be down in 2022 by about 1.2 million t/a, particularly in China and the CIS, with a rebound next year in Africa and south and southeast Asia. However, Peter saw increased consumption out to 2026, mainly from phosphates in spite of a dip this year, but a significant proportion also coming from metals demand, particularly nickel. Supply growth will slow this year, though still overtake demand, but while a number of new projects will see major supply additions after that, mainly in the Middle East and Asia, demand growth may still outpace new supply out to 2026. ■

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Middle East Sulphur Conference 2022

More than 400 representatives from across the global sulphur community convened in Abu Dhabi from 24-26 May 2022 for an exciting new event, the Middle East Sulphur Conference, devoted to exploring best practice operations across the entire sour gas and sulphur value chain.

The Middle East Sulphur Conference (MEScon), organised by CRU and UniverSUL Consulting, with the support of Host Sponsor, Abu Dhabi National Oil Company (ADNOC), took place at the Rosewood Abu Dhabi. This new annual gathering has come about as the consolidation of two previous conferences – MESPON and Middle East Sulphur. The unification of these events and cooperation of their organising partners offers a prime opportunity for the sulphur community to assemble annually in the Middle East, the global epicentre of sulphur production.

Against a backdrop of record sulphur prices and considerations about the future role of the sulphur industry, the inaugural MEScon was positioned at an ideal time to provide a forum to share knowledge and resources in support of continual improvements in HSE, reliability, efficiency and general best practices for the sulphur and sour gas industry.

The opening session on Tuesday 24 May provided key insights into big picture themes, with keynote messages from Tayba Al Hashmi, ADNOC Sour Gas CEO, and Ahmed Mohamed Alebri, ADNOC Gas Processing Acting CEO/ADNOC Industrial Gases Acting General Manager. The role of sulphur as a strategic commodity and ADNOC as a Centre of Excellence were explored in a high-level panel discussion featuring senior ADNOC executives, CRU, UniverSUL Consulting and Alberta Sulphur Research Ltd.

In her opening address, ADNOC Sour Gas CEO, Tayba Al Hashemi, said, "ADNOC's gas growth, including the expansion at Shah and the delivery of the Ghasha concession, will assist in delivering gas self-sufficiency for the UAE and will also help respond to the rising global

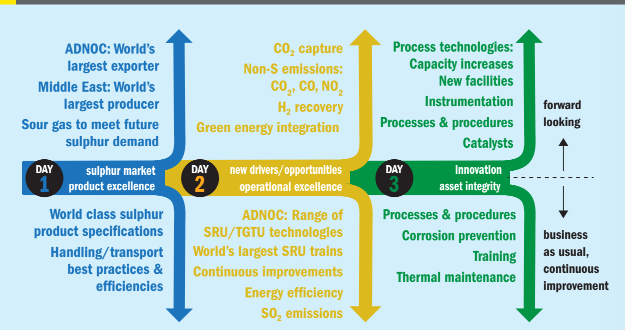
Tayba Al Hashemi's keynote address.

demand for sulphur, which is crucial in meeting the growing global demand for fertilizer and industrial needs. Through continued investment in growth and innovation, ADNOC will build on our position as a safe, competitive, and reliable gas and sulphur producer, to ensure we deliver at the lowest possible cost and lowest possible carbon for our global customers."

Throughout the three-day event, the agenda addressed multiple themes, alternating between forward-looking innovation/technology developments and business-as-usual, best practice knowledge transfer, and continuous improvement, as shown in Fig. 1. Each session began with the overview of a framework by UniverSUL Consulting (see example in Fig. 2), the intention of which was to provide audience perspective on what presentations they would see in the session and how each one relates back to the big picture. Each session concluded with an interactive panel discussion between the audience and all speakers from the session.

The second half of day 1 focused on formed sulphur product excellence, beginning with overarching presentations on sulphur dust and acid prevention from ASRL

Fig. 1: **MEScon 2022 strategic themes**



Source: UniverSUL Consulting


Ahmed Alebri's keynote address.

(Dr Rob Marriott) and DuBois Chemicals (Jeff Cooke), respectively. These were followed by presentations from AKOS Energy (Kent Kalar) and ADNOC Sour Gas (Cesar Zambrano) focused on special considerations and operating experience with sulphur pipelines. IPCO (Casey Metheral) discussed best practices for sulphur granulation and ADNOC Gas Processing (Arivazhagan Rajendran) wrapped up the session with a presentation on fire detection in sulphur handling facilities.

The first half of day 2 was dedicated to new drivers and opportunities in sulphur recovery. ADNOC Gas Processing (Saqib Sajjad) got the session underway with a presentation on green energy opportunities in sour gas/sulphur plants, followed by Comprimo (Camille Ventham) and Fluor (Thomas Chow), who each presented alternatives for CO_2 capture and H_2 recovery from sulphur plant tail gas. The session then shifted toward non-sulphur emissions from sulphur recovery units, with presentations from both SICK A.G. (David Inward) and Koch Engineered Solutions Middle East (Gernot Schwarting).

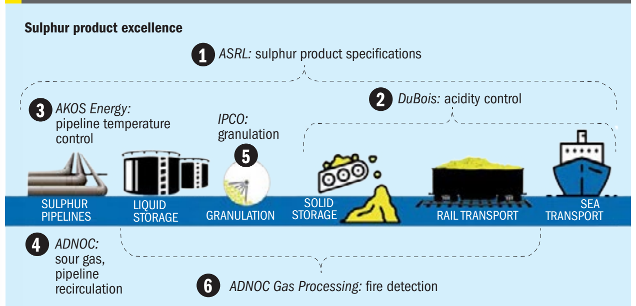
The afternoon of day 2 turned toward the more traditional focus of sulphur plants – SO_2 emissions and operational best practices. The first presentation was provided by Ibrahim Khan and Afra Al Mansoori and offered insights into ADNOC Gas Processing's efforts to reduce SO_2 emissions in existing sulphur recovery facilities at Habshan and Ruwais. This was followed by a presentation from ADNOC Sour Gas (Al Sail Al Jaberi), which provided an overview of a recent sulphur recovery unit (SRU)/tail gas treating unit (TGTU) catalyst optimisation scheme in the world's largest SRU/TGTU trains. Khalid Hinai then shared valuable lessons learned during the recent start-up of Petroleum Development Oman's (PDO's) largest sulphur recovery complex (Yibal Khuff), which is equipped with Cansolv tail gas treating technology. Finally, the session concluded with an interesting talk from ADNOC Gas Processing, showcasing recent efforts to optimize BTEX destruction in the Habshan 5 SRU/TGTU trains.

The third and final day of MEScon was dedicated to innovation in the morning and asset integrity in the afternoon. The first presentations of the morning session focused on innovations in gas treating and tail gas treating solvents from Dow and BASF (presented by Lorenzo Spagnuolo and Ashraf Abufaris, respectively). Delta Controls (Matt Coady) then gave a presentation on unpurged thermal reactor thermocouples – the second of two innovations presented by Delta Controls at MEScon 2022. The first innovation – a new thermal reactor camera - was announced on day 1 and displayed at Delta's exhibition booth throughout the three days of the event. Euro Support (Mark van Hoeke) gave a presentation on innovations in TGTU catalyst presulphiding using titania catalyst and the session was concluded with an innovative approach toward automating SRU/TGTU start-up and shutdown, provided by Raghesh Karunakaran (ADNOC Gas Processing).

The first presentation of the afternoon session spanned both innovation and asset integrity, as Jaime Aguilera demonstrated Voovio's technology, which uses digital replicas and simulators to enable efficient operator onboarding, increased productivity, reduced downtime, and improved asset integrity. The focus then shifted toward corrosion aspects related to asset integrity, with presentations on thermal maintenance (Justin Tucker, Ametek CSI), waste heat boiler tubesheet protection (Domenica Misale-Lyttle, Industrial Ceramics Limited) and tail gas absorber overhead piping corrosion (Muhammed Nisar and Alya Al Ali, ADNOC Gas Processing).

Feedback from the inaugural MEScon event has been positive. In the future, with the region's prominence in the global sulphur industry, MEScon is expected to play a vital role in articulating the key strategic themes that are driving the industry. This includes how the region as the world's largest producer of sulphur, and ADNOC as the largest exporter, are marrying operational experience with best-in-class technology to meet global sulphur demand whilst maintaining the highest levels of sustainability and efficiency. ■

Fig. 2: **Overview framework for MEScon day 1, second half**



Source: UniverSUL Consulting

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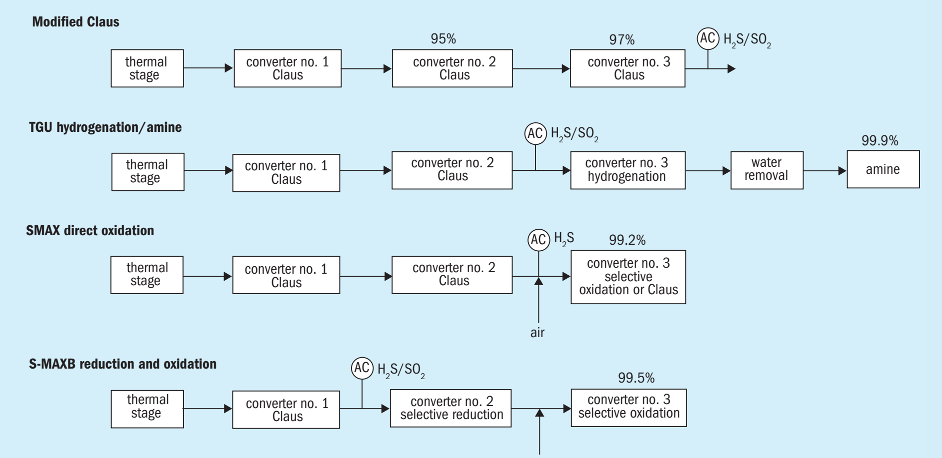
Advanced catalysts meeting the need for stricter regulations

M. Rameshni and **S. Santo** of Rameshni & Associated Technology & Engineering (RATE USA) report on advanced catalysts for increasing the sulphur recovery efficiency of new and existing sulphur recovery units to meet stricter environmental regulations.

Fig. 1: **Different technology concepts for sulphur recovery**



Source: RATE

The US and Europe are required to meet SO_2 emission limits ranging from 250 ppmv to less than 50 ppmv depending on the local regulations. The World Bank has also set the SO_2 emission limit to less than 50 ppmv for the funding of new investments which translates to a recovery of 99.99%. However, in other countries like Canada, Mexico, some of the countries in the Middle East and CIS region, especially Russia, Kazakhstan and Uzbekistan, such tight regulations are not required. A number of years ago, sulphur recovery units were designed for plants in Canada, Mexico and other locations which included a conventional tail gas treating unit after the sulphur recovery units but since there was no requirement for tight SO_2 emission limits, the tail gas treating units were never built or the facility never started up their new tail gas unit as the three-stage Claus unit followed by the incineration was adequate.

In some cases, not using the tail gas treating unit resulted in severe corrosion and in some cases the tail gas treating unit was demolished. The three-stage Claus unit can meet a sulphur recovery efficiency of 95-97%. Recently, in the locations previously mentioned new environmental regulations now require them to increase the sulphur recovery to between 98.5% and 99.5%. These facilities are looking for a robust, simple and reliable solution to increase the recovery with the minimum investment, minimum shutdown period, minimum or no training and no pre-investment for recovery beyond 99.5%.

Changing the typical Claus catalysts to more advanced formulated catalysts could

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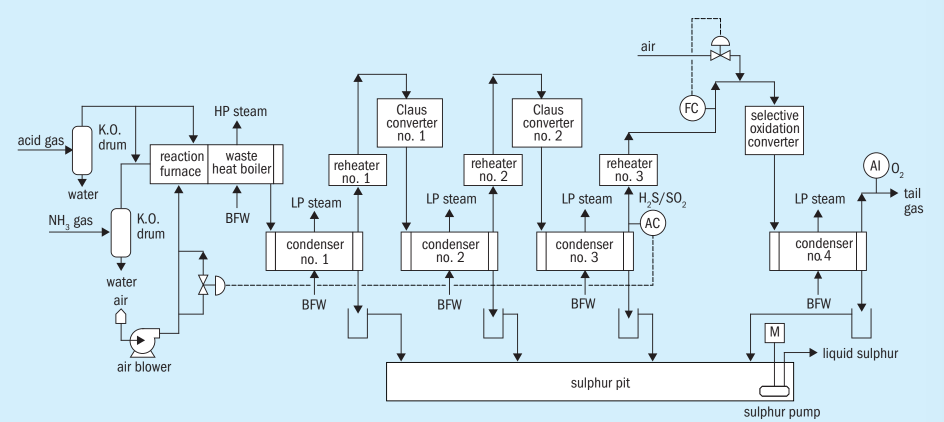
Fig. 2: **Three-stage Claus with SMAX-100 direct oxidation catalyst**



Source: RATE

increase the sulphur recovery up to 99.5% and will meet such regulations with minimum modifications to the existing units as described in this article.

RATE has developed two catalysts SMAX-100 and SMAXB-100 for the selective oxidation of H_2S to sulphur and selective reduction of SO_2 to sulphur.

RATE has implemented these catalysts for grass roots units and the revamp of existing sulphur recovery units in more than 20 units. This patented technology was granted by the US Patents office in 2015.

The concept of how these technologies can be implemented is shown in the block diagram in Fig. 1.

The sulphur recoveries shown in the block diagram represent the maximum achievable recovery, the ultimate recovery depends on the feed composition especially the H_2S concentration and the presence of ammonia and other impurities.

SMAX-100 catalyst

The SMAX-100 is located in the last catalytic stages of the sulphur recovery unit. A slim stream of air from the combustion air blower is mixed with the tail gas stream after the final reheater and enters the SMAX reactor. Organic sulphur species that are generated in the thermal stage are hydrolysed to H_2S in the catalytic stages and converted to sulphur in the last reactor to increase sulphur recovery. As a result, the Claus unit can be operated at the optimal H_2S/SO_2 ratio, it is not sensitive to changes in H_2S/SO_2 ratio, and provides process reliability, stability, and ease of the control system.

The SMAX direct oxidation concept comprises three steps:

- a conventional Claus thermal stage ;
- two Claus catalytic stages;
- a selective oxidation stage that converts H_2S to elemental sulphur.

The gas from the third condenser is reheated in the third reheater, and flows to the third converter, the S-MAX reactor. Air from the combustion air blower is piped to the reactor where it mixes with the feed prior to entering the S-MAX reactor.

The remaining H_2S is reacted with O_2 to form elemental sulphur in the presence of direct oxidation selective oxidation catalyst. The converter effluent is cooled in the last (fourth) sulphur condenser, before the tail gas is routed to the incinerator. An oxygen analyser located at the outlet of the last sulphur condenser is used to control the process air added to the selective oxidation converter. The tail gas stream flows to the sulphur coalescer to recover any entrained sulphur. The recovered sulphur then flows to the sulphur pit through the sulphur seal and the tail gas feed flows to the incinerator.

The direct oxidation catalyst has demonstrated its flexibility in adapting to various swings in process operating conditions, such as high and low turndown feed rates, various water content (up to 40%), and various H_2S concentrations in the feed. Under this wide range of operating conditions, the direct oxidation catalyst maintains its high activity and selectivity. The direct oxidation catalyst promotes the selective direct oxidation of H_2S to sulphur as indicated by the following reaction:

$$H_2S + \tfrac{1}{2}O_2 = 1/x\ S_x + H_2O$$

Besides the main reaction, a small amount of SO_2 is also formed according to the following side reactions:

$$H_2S + 1\tfrac{1}{2}\ O_2 = SO_2 + H_2O$$

$$1/x\ S_x + O_2 = SO_2$$

Fig. 2 shows the overall process flow diagram of the three-stage sulphur recovery unit where the last reactor contains SMAX-100 direct oxidation catalyst.

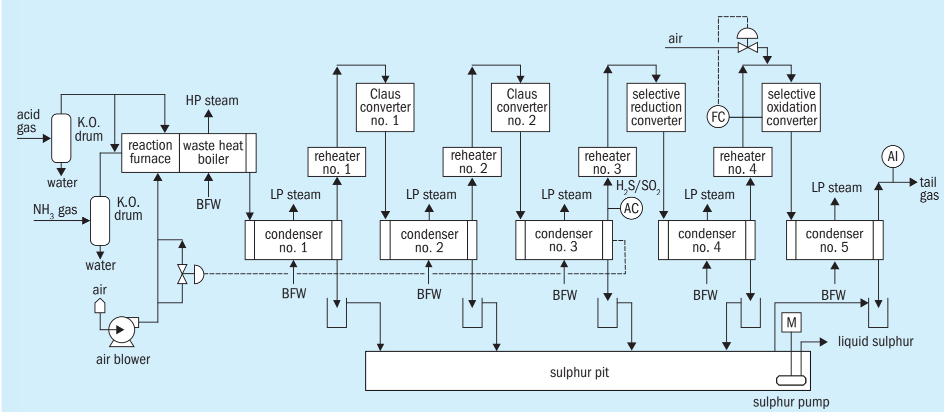
SMAXB-100 catalyst

SMAXB-100 is a direct reduction catalyst that is located in the second reactor of a third-stage Claus unit or in the third reactor of a fourth-stage Claus unit depending on the desired recovery.

In order to comply with up to 99.5% recovery requirements and to minimise the investment and the capital cost RATE offers the S-MAXB direct reduction and oxidation process. This tail gas treating scheme consists of four steps:

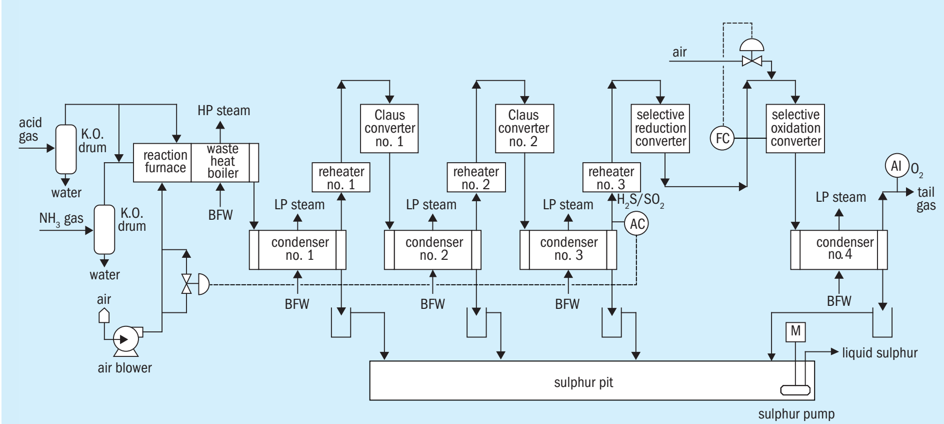
- a conventional Claus thermal stage;
- at least one Claus catalytic stage;

Fig. 3: **Four-stage Claus with SMAX and SMAXB catalysts**



Source: RATE

Fig. 4: **Four-stage Claus with SMAX and SMAXB catalysts**



Source: RATE

- a selective reduction stage that converts SO_2 to elemental sulphur;
- a selective oxidation stage that converts H_2S to elemental sulphur.

Taking advantage of the H_2 and CO produced in the Claus reaction furnace as reducing gas for the selective reduction of SO_2 to elemental sulphur, no external supply of reducing gas is necessary. The description of the oxidation stage is the same as described for SMAX-100 catalyst.

Fig. 3 represents a four-Stage Claus unit where the SMAXB catalyst is located in the third stage and SMAX is located in the fourth stage.

In some cases, the third condenser and the fourth reheater after the SMAXB is eliminated as the SMAXB reactor provides an adequate temperature to the SMAX reactor (see Fig. 4). And in some cases, the SMAXB catalyst is added to the second Claus reactor and the SMAX is added to the third Claus reactor as shown in Fig. 5.

SRU revamp for increased recovery

Short descriptions of the modifications to existing SRUs in some current projects are listed below:

- **Retrofitting existing two-stage Claus to 2+1 SMAX:** requires adding a third reactor (with selective oxidation catalyst) to existing two-stage Claus SRU. Most of the work can be done as add-on, skid-mounted units with no need to shut down, however, tie-in of the third reactor, piping,

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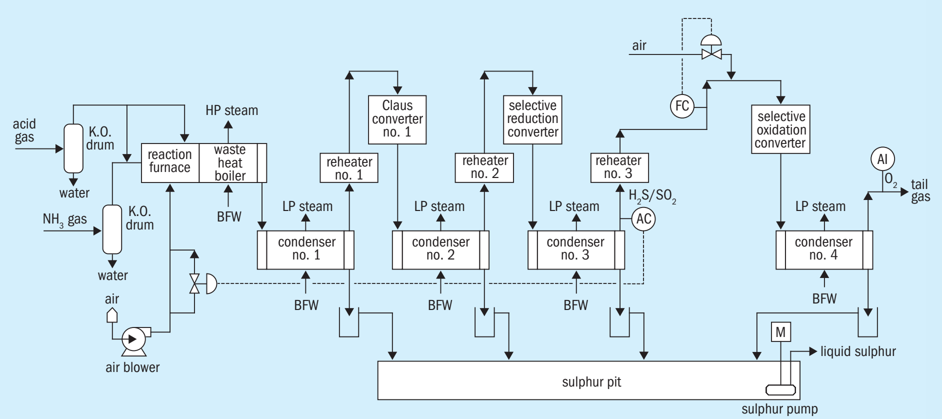
Fig. 5: **Three-stage Claus with SMAX and SMAXB)**

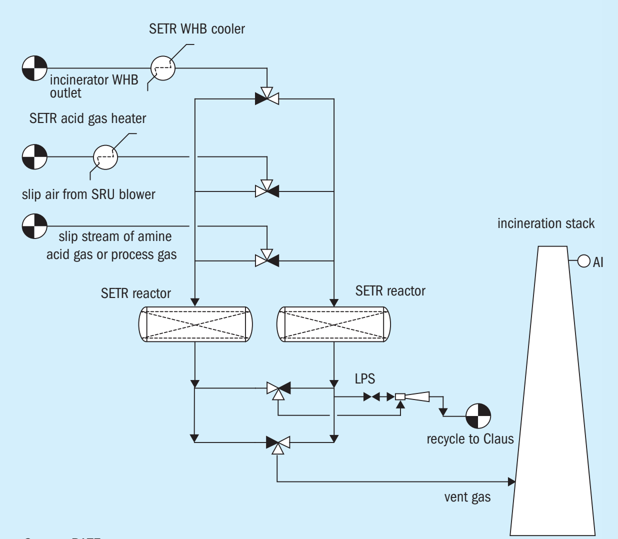


Source: RATE

instruments, utilities, etc. requires ≈ two weeks of unit shutdown and will improve the recovery efficiency from the current 95% to 99% or 99.1% depending on the H_2S concentration.

- **Retrofitting existing two-stage Claus to 3+1 SMAX:** requires adding a third reactor (with conventional Claus catalyst) and a fourth reactor (with selective oxidation catalyst) to the existing two-stage Claus SRU. Again, most of the work can be done as add-on, skid-mounted units with no need to shut down, however, tie-in of the third and fourth reactors and associated piping, instruments, utilities, etc. requires two to three weeks of unit shutdown and will improve recovery efficiency from the current 95% to 99%-99.4%.
- **Retrofitting existing two-stage Claus to keep 2+1 SMAX:** requires changing the catalyst in the second existing reactor (with combined conventional Claus + reduction catalyst) and adding a third reactor (with selective oxidation catalyst) to the existing two-stage Claus SRU (adding only one reactor and changing the catalyst in the second reactor). Again, most of the work can be done as add-on, skid-mounted units with no need to shut down, however, tie-in of the third reactor and associated piping, instruments, utilities, etc. requires three to four weeks of unit shutdown and will improve recovery efficiency from the current 95% to 99.2%-99.3%.

Fig. 6: **SETR process with SETR ADS 700**



Source: RATE

- **Retrofitting existing two-stage Claus to 3+1 SMAXB:** requires adding a third reactor (with combined conventional Claus + reduction catalyst) and a fourth reactor (with selective oxidation catalyst) to the existing two-stage Claus SRU. Again, most of the work can be done as add-on, skid-mounted units with no need to shut down, however, tie-in of the third and fourth reactors and associated piping, instruments, utilities, etc. requires three to four weeks of unit shutdown and will improve recovery efficiency from the current 95% to 99.2%-99.6%.

In all four projects listed above the pit vent stream from the sulphur pit or degassing that contains H_2S can be recycled to the front of the SRU instead of the incinerator to increase increase the sulphur recovery further. It would require more cost to recycle the pit vent stream.

The modifications required in these projects are minimal:

- if a new additional reactor is needed it can be fabricated separately, and installed during a short shutdown;
- install new (horizontal or vertical) thermowells (minimum four thermowells for four thermocouples across the height of the reactors) and relocate the existing thermowells as needed;
- replace conventional catalyst with SMAX and possibly SMAXB;
- replace the retaining grid and screens inside the reactor;
- touch up the reactor refractory as needed.

SETR ADS 700 catalyst

SETR ADS 700 is an activated alumina-based adsorbent and has the same catalyst life as Claus catalyst (four to five years).

> **"This scheme will increase sulphur recovery efficiency from 99.5% to 99.9%-99.99%."**

SETR is another patented technology which is located after the incinerator and before the stack. The technology can be applied after any type of a tail gas treating unit, including the SMAX and SMAXB processes described earlier, in cases where the sulphur recovery needs to be increased beyond 99.5%. There is no need for the conventional tail gas treating. SETR can be added after the incinerator and before the stack.

The main difference is that sulphur is recovered and recycled back to the SRU. Caustic treatment generates a waste stream but there is no waste stream from SETR. This scheme will increase sulphur recovery efficiency from 99.5% to 99.9%-99.99%.

Retrofitting an existing two-stage Claus to one of the configurations in Figs 2-5, SMAX/SMAXB plus SETR can achieve the ultimate sulphur recovery or zero SO_2 emission.

Fig. 6 represents the SETR process where the catalyst is supplied through RATE.

Summary and conclusions

RATE has developed two catalysts to increase the sulphur recovery from 95% up to 99.5% by using SMAX -100 and SMAXB-100. These catalysts can be used in new or existing sulphur recovery units with no size limitation. The life of the catalysts is the same as Claus catalysts, four to five years.

For sulphur recovery efficiencies of greater than 99.5%, RATE has developed the SETR ADS700 catalyst and process which can be added after the incinerator and before the stack.

Sulphur recovery depends on the feed compositions and is evaluated on a case-by-case basis.

All three catalysts including the process schemes are patented technologies, licensed by RATE as part of the technology licensing.

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The consequences of condensate formation in acid plants

Condensate formation in sulphuric acid plants can cause severe corrosion problems leading to high maintenance and plant downtime. **Santhosh S.** of Metso Outotec discusses the importance of carrying out regular monitoring and maintaining accurate and detailed data about condensate to increase equipment life and avoid downtime. Different sources of condensate formation in the plant are discussed as well as the typical locations in the plant where the condensates end up.

The condensate in a sulphuric acid plant is a key indicator of its overall condition. If left unchecked or not given sufficient attention, it can cause severe corrosion problems leading to high maintenance and downtime of the plant.

Not much importance has been given to this subject in the majority of acid plants and record keeping of condensate readings are rarely followed.

The following sections aim to throw some light onto this subject pertaining to both metallurgical and sulphur burning plants. In the acid plant flowsheets shown in Figs 1 and 10, various sources of condensates are marked with numbers and the locations of where they tend to show up is marked with letters for easy reference.

Metallurgical acid plants

A flowsheet of a typical metallurgical acid plant is shown in Fig. 1.

Typical sources of condensate are highlighted in the following sections.

Wet electrostatic precipitator *(1)*

99% of the residual mist contained in the gas leaving the wet electrostatic precipitators (ESPs) are generally <1 micron in size and poor function of the ESPs can lead to a stack plume (g). Submicron particles will neither evaporate nor condense as condensate collection due to the fineness of the mist and thus can persist throughout the acid plant. If there is a considerable amount of NOx present, the colour of the plume may be yellowish to brownish.

Drying tower *(2)*

The next source of condensate can originate from the drying tower (DT). It is mainly caused by acid carryover or poor gas drying.

- **Acid carryover** from the DT will be first evident on the acid trap *(a)* located on the DT outlet duct. Usually, the outlet duct from DT is sloped downwards and the trap is located on the bottom of the duct, upstream of the main blower gas inlet. A periodic record of the quantity of condensate with relation to airflow/production from the time of plant start-up is necessary to compare the severity of acid carryover. Acid condensing at the gas duct wall and larger drops can be separated there. Provided that the DT-demister is functioning properly, no significant quantity of condensate will be collected at this acid trap. However, smaller droplets will pass on further downstream of the plant, usually impacting on the shell side of the cold heat exchanger CHE *(b)*, thus separating from the gas-flow, and drain as condensate from the shell side. Part of those droplets/mist will pass through the heat exchanger and partly evaporate into gaseous H_2SO_4, which will subsequently condense at "cold" surfaces, e.g., the tube-side of the cold reheat exchanger i.e., bed 3 outlet stream *(c)*.
- **Poor gas drying** leads to moisture slippage and will lead to the formation of H_2SO_4 vapours after the reaction with SO_3 formed in the converter. Due to the high temperature in the converter, they remain as vapour but start to condense as soon as they are exposed to cold spots with a temperature lower than the dew point of the gas. The dew point of the gas is directly proportional to the moisture content of the gas as shown in (Fig. 2).

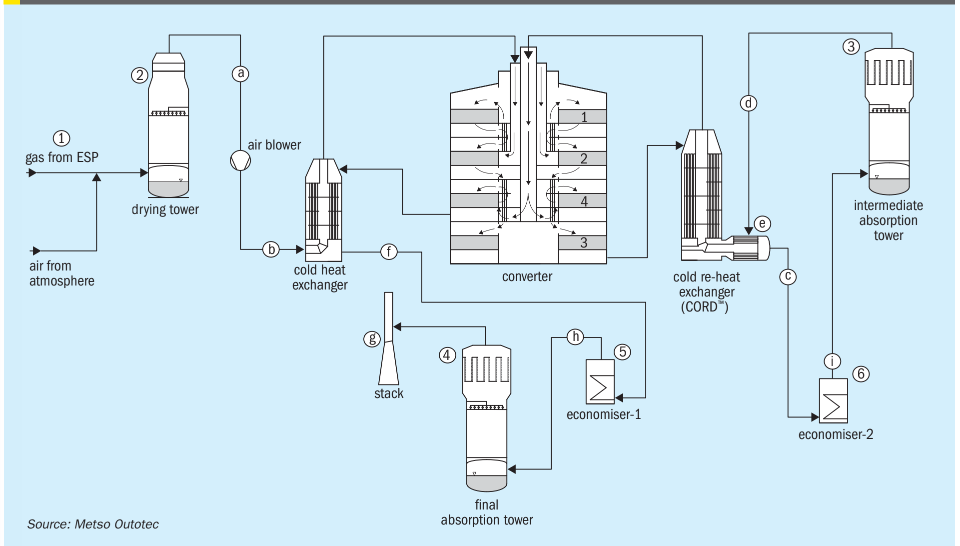
From the graph in Fig. 2, it is evident that the higher moisture content will lead to higher dew points enabling condensate formation at higher temperatures. A moisture content of <30 mg/Nm³ is excellent, <50 mg/Nm³ is good and anything above 50 mg/Nm³ is not recommended and should be investigated. Moisture content of the DT gas exit should be tested at least twice a year to keep a record on the performance of the drying tower.

When the metal surface temperature on the tube side of the cold reheat exchanger drops below the dewpoint, acid condensation will occur there. A simple stick test on the DT outlet will allow the operator to conclude and identify the root cause of carryover in the drying tower and differentiate between acid carryover and moisture carryover. Once again records (photos, as shown in Fig. 3) of periodic stick tests vs gas flows will enable the history to be interpreted and will provide a better understanding of the present operating conditions.

Intermediate absorption tower *(3)*

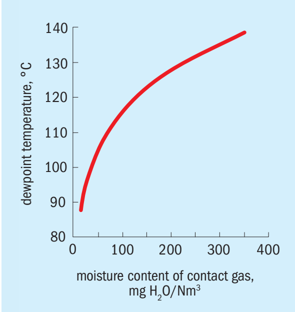
The gas outlet of the intermediate absorption tower (IAT) is the next source of condensate in the metallurgical acid plant. It can be caused by acid carryover, wrong concentration leading to moisture content in the gas, or SO_3 slippage.

Fig. 1: **Typical metallurgical acid plant flowsheet**



Source: Metso Outotec

Fig. 2: **Sulphuric acid dewpoint of contact gas vs moisture content**



Source: Metso Outotec

Large droplet acid carryover from the intermediate absorption tower will be first evident on the acid trap *(d)* located on the IAT outlet duct. Although most of the quantity is collected on the trap, high loads of carryover will slip to the cold reheat exchanger typically on the shell side *(e)*, and in severe cases it will appear on the tube side of the cold heat exchanger i.e., bed no. 4 outlet *(f)*.

Condensation in the cold reheat exchanger will lead to corrosion of the tube walls, forming form sulphate scale, which in turn leads to higher pressure drop. High amounts of fouling will start to affect the heat transfer area of the exchanger (Fig. 4) and contribute to operating costs of the blower due to the additional pressure drop. Significant drain will reduce the lifetime of the heat exchanger and the whole unit will have to be replaced leading to significant capital investment and downtime.

CORD™ heat exchangers of Metso Outotec plants (Fig. 5) are specially designed in view of this problem and to help reduce the corrosion damage in case of condensate problems. The CORD™ heat exchanger has a small stainless-steel bundle on the cold side of the gas where the condensation first occurs. The gas temperature at the outlet of this bundle is above the typical dew point temperature, which ensures the second bundle (the main tube bundle) remains free of corrosion. In case of corrosion, the small tube bundle can be replaced without touching the main long bundle, thus saving significant costs of replacing the entire heat exchanger.

In the rare case of too low or too high acid concentration, resulting in low absorp-

Fig. 3: Drying tower stick tests. Left: clean. Centre: Some carryover. Right: Severe carryover.

PHOTOS: METSO OUTOTEC

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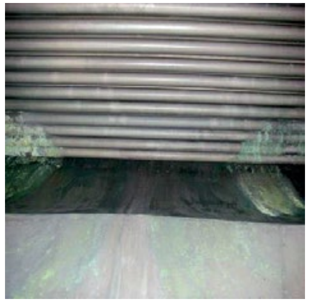


PHOTO: METSO OUTOTEC

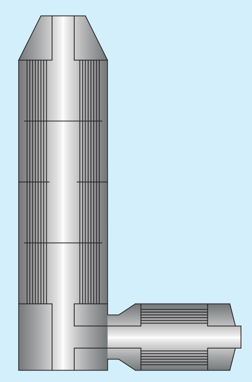
Fig. 4: Sulphate formation on shell side of cold reheat exchanger.

tion and high partial pressures of water or SO_3 on top of the intermediate absorption tower, dew point condensation can occur as discussed earlier. Fig. 6 illustrates the partial pressures of the gas components above sulphuric acid at 80°C.

This is unusual as the operators generally have good control of the acid concentration to the tower. This will be evident on the cold heat exchanger tube side i.e., bed no. 4 outlet *(f)* which is the first cold location where H_2SO_4, SO_3 gas and moisture may condense.

A simple stick test on the IAT outlet (Fig. 7) will allow the operator to identify larger droplet carryover and differentiate it from any vapour, e.g., SO_3 slippage. Once again, recording of periodic stick tests vs gas flowrate/plant load is necessary to analyse the current operating conditions.

Fig. 5: **CORD™ (European Patent EP 2 742 303 B1)**

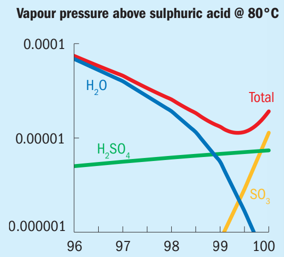


Source: Metso Outotec

Another simple test to identify SO_3 slippage from the intermediate absorption tower is to observe the colour of the gas from the IAT outlet from a sample point (Fig. 8). If the gas contains SO_3, the gas becomes white as soon as it is in contact with moisture in air due to the reaction between SO_3 and water vapour.

The acid distributor design in the tower is also crucial to ensure good absorption and to minimise carryover. The acid irrigation rate, gas velocity, tower size etc. must be taken into consideration during

Fig. 6: **Sulphuric acid vapour pressure vs concentration**



Source: Metso Outotec

the design phase and also duri$_3$ng debottlenecking and capacity increase projects later on during operation.

A dedicated branch of Metso Outotec in Gothenburg, Sweden, deals with the design of equipment in contact with acid and can offer solutions to design or debottlenecking requirements in the acid section (Fig. 9).

Final absorption tower *(4)*

The reasons for condensate from the final absorption tower (FAT) are similar to those already discussed for the intermediate absorption tower as both towers function in exactly the same manner and will appear in drain of the stack *(g)*. High carryover will cause stack spitting and will require prompt action. Moderate amounts of condensate from a stack is normal. Again, regular stick tests provide valuable information on history and present operation.

Most countries have an emission norm requiring a limit of 25-30 mg/Nm³ of H_2SO_4 in stack emissions.

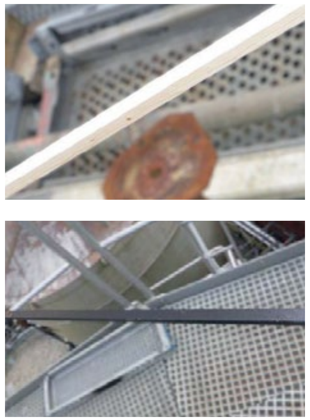

PHOTOS: METSO OUTOTEC

Fig. 7: Stick Test for IAT. Top: clean. Bottom: Uniform charring of the wood signifying SO_3 slippage.

Fig. 8: White colour in the IAT outlet gas indicating SO_3 slippage.

Sulphur burning acid plants

A flowsheet of a typical sulphur burning acid plant is shown in Fig. 10.

Typical sources of condensate are highlighted in the following sections.

Sulphur *(1)*

Hydrocarbons in sulphur burn in the furnace to form carbon dioxide and water vapour. The water content will react with sulphur trioxide generated during the combustion of elemental sulphur with air resulting in the same phenomena as discussed in the drying tower section.

Drying tower *(2)*

The same reasons and detection methods apply as discussed in the metallurgical acid plant section.

Economiser-boiler-superheater *(5-9)*

Steam or water leakage from the waste heat boiler and superheater will cause rapid moisture ingress in the gas going into the converter. The steam/water will react with SO_3 in the catalytic beds and if in large quantity usually will only condense in cold areas of cold heat exchanger tube side *(c)* and the economiser 2 drain *(i)*.

A BFW leak from the economiser 2 will cause rapid moisture ingress in the gas going into the. A small leak will still not result in any condensate as the gas going to the intermediate absorption tower still has a temperature of 160-180°C and will be in the vapour state. However, as the leak progresses, the dew point increases and the economiser 2 drain will start showing condensate. In severe cases, i.e., with significant water leakage from the waste heat boiler or superheater, condensate can also be found on the cold reheat exchanger tube side.

The effect of a leakage from economiser 1 *(h)* is similar to economiser 2. However, a leak in economiser 1 will also contribute to a plume in the stack *(g)*, as the mist formed in the final absorption tower will overload the candles and escape to the stack.

The ingress of water/steam to towers will generate great deal of mist which can lead to a rise in candle filter pressure drop and start affecting the dilution water quantity depending on the gravity of the leakage.

The leak will slowly decrease the dilution water quantity in the acid section (Fig. 11), but a small leak is generally hard to detect and only becomes evident when the leak becomes large enough. This can take a significant time, up to several days, when continuously increasing amounts of condensate can build up. There may also be an increase in the candle filter pressure drop in the IAT/FAT as the moisture ingress in the gas will lead to substantial mist formation in the towers.

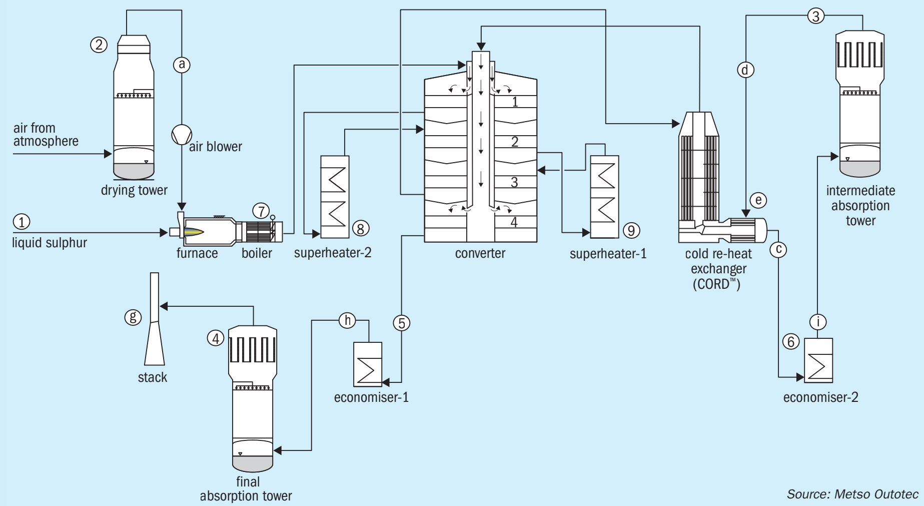
For this reason, dilution water quantity flow and control valve opening should be regularly monitored as this usually can be assumed as a constant for a given production and air flow. Any sudden change in the control valve position and water flow should be investigated.

Metso Outotec's new HIPROS™ design overcomes the problem of low temperature BFW entering the economisers, thus eliminating dew point problems and corrosion


PHOTOS: METSO OUTOTEC

Fig. 9: Edmeston SX® alloy distributors from Metso Outotec. Left: FiDi European Patent EP 2 173 464 B1. Centre: Lurgi deflector plate. Right: Trough type.

Fig. 10: **Typical metallurgical acid plant flowsheet**



Source: Metso Outotec

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in the economisers. The deaerator in the HIPROS™ design is pressurised to 9-10 bar and the BFW temperature is about 180°C entering the economisers, instead of the typical 105°C. This ensures a wide temperature margin between the tube wall temperature and typical gas dewpoint. This higher temperature also leads to higher high pressure steam generation (around 11% increase over conventional design).

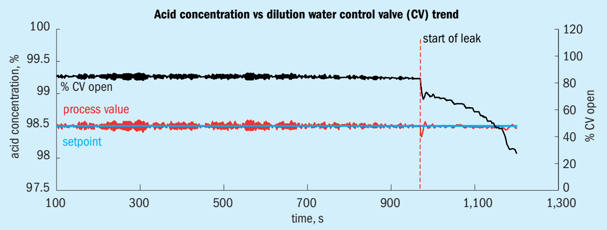
Intermediate absorption tower *(3)*

The same reasons and detection methods apply as discussed in the metallurgical acid plant section.

Final absorption tower *(4)*

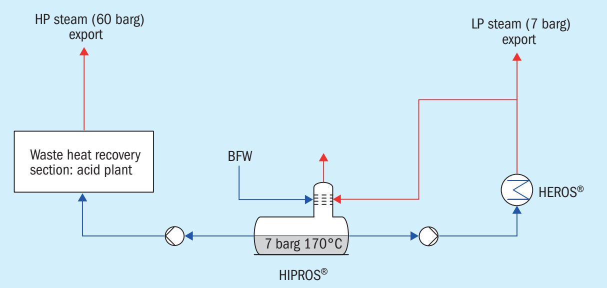
The same reasons and detection methods apply as discussed in the metallurgical acid plant section.

Fig. 11: **DCS trend of acid concentration during a steam/boiler feed water leakage**



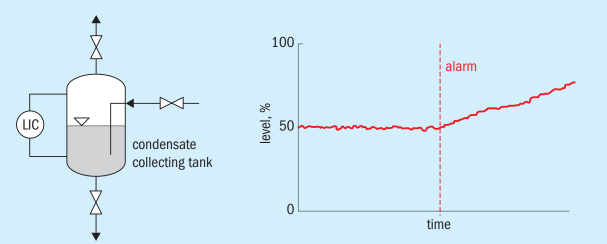
Source: Metso Outotec

Fig. 12: **HIPROS European Patent EP 1 851 170 B1, HEROS European Patent EP 3 233 723 B1**



Source: Metso Outotec

Fig. 13: **Condenate collection/monitoring**



Source: Metso Outotec

How much condensate is normal?

As discussed in the previous sections the sources of condensate are numerous, especially in a sulphur burning acid plant. It is very important to have a detailed log of condensate at various points of the plant. These should preferably be tabled in the plant logbook as it is as important as other process values. A good log history will allow the operator to compare the results of normal plant operation with abnormal operation and to assess the gravity of the problem.

Periodic laboratory analysis of condensate will also give valuable insights of the equipment conditions and corrosion rates. A milky condensate indicates sulphates, a greenish or blueish colour usually indicates a high chromium or nickel content. The metal content can provide an indication of the severity of corrosion rates if the condensate is analysed frequently. In the modern world of digitalisation, it is possible to monitor the condensate generation in various points of the plant by using simple instrumentation loops. One such concept is shown in Fig. 13.

The condensate is collected in the container and the level is monitored by a level transmitter.

The rate of condensate formation is related as a function of level increase vs time. Any increase in the rate will signal an alarm and the operator can check and eliminate various reasons as discussed earlier.

If applied to all the condensate points identified in this discussion, this concept will require a few more instruments in the plant. Also, the instrument ports will require some maintenance and cleaning as the condensate may also cause acid sludge build-up and can easily block the instruments if left unattended.

The question to ask is whether to ignore condensate monitoring be it manual or by digital methods and to pay the price in corrosion, equipment replacement and downtime or to carryout regular monitoring and maintain accurate and detailed data about condensate to increase equipment life and avoid downtime.

As for the amount of condensate acceptable at each of the locations discussed above, there is no general rule. This will depend on the plant load and size/capacity of the acid plant. As a general rule of thumb, for a typical 2,000 t/d acid plant, an amount of 0.5-1.0 litre/day of condensate at the coldest spots (cold heat exchanger, cold reheat exchanger, economiser) would present an acceptable normal quantity. ■

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Simple tests to keep problems at bay

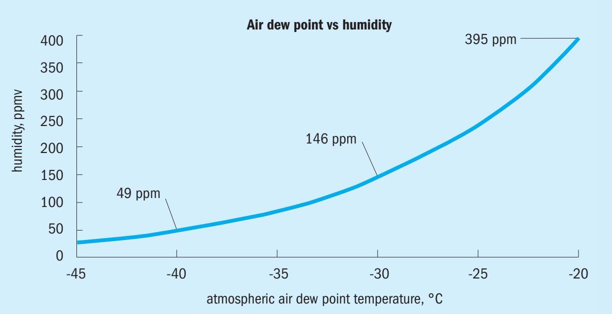
E. Almeida and **B. Ferraro** of Clark Solutions discuss how regular monitoring by simple testing of the towers in sulphuric acid plants can improve the reliability and lifespan of the plant.

Planning and strategy are imperative for an efficient sulphuric acid plant maintenance shutdown. Often, the need to substitute tower internals is only perceived when the status is critical, when abrupt process oscillations occur, or only at the moment the tower is opened.

Being in such a situation causes delays in downtime, requires urgent decision making and the selection of stop gap solutions and, in the worst-case scenario, production is stopped until the damaged item has been manufactured.

Predicting when tower internals need to be substituted is extremely important to enhance plant reliability and lifespan and can be determined by simple tests if executed in a frequent and correct manner, providing enough time to decide between a repair or acquisition of a new piece of equipment.

Fig. 1: **Atmospheric air dew point temperature vs humidity**



Note: Estimated values, may vary with altitude and relative humidity.

Source: Clark Solutions

Simple tests

A wide range of tests can be executed to evaluate the health of a sulphuric acid plant. Clark Solutions believe three of the most basic and practical tests are:

- dew point at the drying tower;
- Kitasato test at the absorption tower;
- stick test at the drying and absorption towers.

These tests can be performed weekly or monthly requiring minimal resources.

The tests reveal relevant information which can be used to infer weak points in the plant. The results indicate which equipment demands attention in the next scheduled shutdown.

As a disclaimer, test descriptions in this article are for illustrative purposes. It is highly important that tests are performed safely and reliably, following all protocols for execution, and with all personnel wearing all necessary personal protective equipment.

PHOTOS: CLARK SOLUTIONS

Fig. 2: Dew point test device.

Dew point test

The dew point test indicates the health of internals and operation in drying towers. It shows the tower drying capacity in a quantitative manner (usually precise to within 2 to 3°C). The test measures the dew point of the outlet gas stream. With this value, it is possible to estimate the remaining water concentration (Fig. 1) of the gas stream.

A dew point test can be easily performed in a Lectrodryer device or similar, as illustrated in Fig. 2. While feeding dry gas to the device, using the tower's positive pressure or with the support of a vacuum pump in negative pressure towers, dry ice and acetone are placed on the inner side of the device's polished cup, together with a thermometer. As the acetone and dry ice evaporate, heat is removed from the mixture

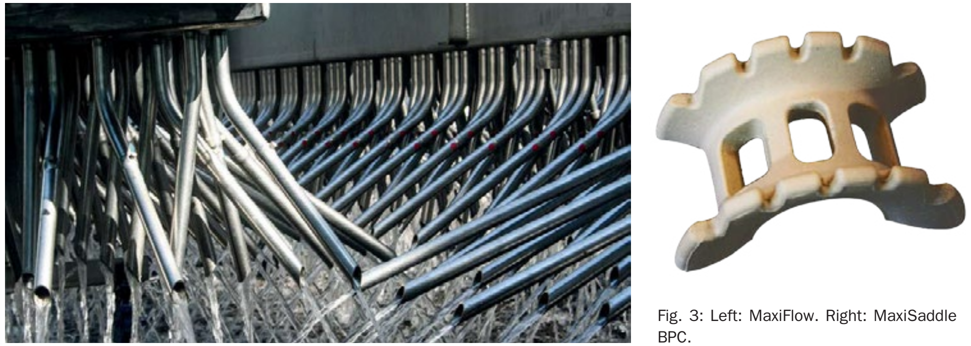


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Fig. 3: Left: MaxiFlow. Right: MaxiSaddle BPC.

and the temperature drops continuously. As it decreases, the polished cup outer surface cools down. As the temperature decreases, one must observe the sight glass and the cup outer surface. When the smallest trace of condensation is observed, the dew point temperature displayed on the thermometer is registered.

A dew point of around -40°C is an indication of very good air dryness. Dew points above -30°C are cause for concern, particularly on plants with low temperature economisers and other low tube wall temperature devices.

Evaluation of tests results are better described in Clark Solutions' article in *Sulphur* no. 396 pp. 38-41 (Sep-Oct 2021). Summing up, high dew point could reveal issues such as: insufficient acid irrigation (by distributor or circulating flowrate), inadequate irrigation temperature, packing preferential paths and more.

Tower internals such as ceramic saddles e.g., MaxiSaddle® and liquid distributors e.g., Maxiflow® could assist in providing better operation.

Kitasato test

The Kitasato test (Fig. 4) indicates the health of the internals and operation in absorption towers. It shows humidity, sulphuric acid entrainment and/or SO_3 presence in a qualitative manner.

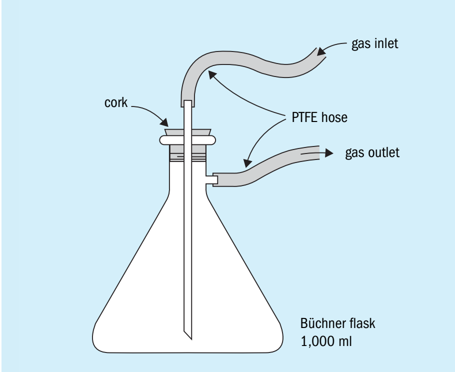
The visual results are listed below and are referred by number later on:

1. Whiteish gas formation in the flask interior as well as deposition of sulphuric acid droplets at the flask bottom may indicate the presence of humidity (Fig. 5).
2. White smoke formation at the PTFE hose outlet (outside the flask) may indicate SO_3 in the gas.
3. Sulphuric acid deposition inside the flask may indicate sulphuric acid entrainment.
4. No smoke formation nor liquid accumulation inside the flask is also possible.

The test can be carried out with a Büchner flask (also known as Kitasato), cork and PTFE hose, as shown in Fig. 4. It is mainly applied in two typical positions: between the converter and the absorption tower and the absorption tower outlet, bringing different interpretations of the results.

The presence of humidity is often evaluated between the converter and the absorption tower, where a gas with SO_3 and negligible water content is expected. If the plant is performing accordingly, only result 2 is observed, since the SO_3 in the gas stream goes through the flask and only reacts with atmospheric humidity when it

Fig. 4: **Kitasato configuration**



Source: Clark Solutions

PHOTO: CLARK SOLUTIONS

Fig. 5: Results 1 and 2 happening simultaneously (typical presence of humidity between converter and absorption tower).

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1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25

leaves the system, generating a sulphuric acid fine mist that is perceived as a white smoke. On the other hand, if the humidity is higher than expected, results 1 and 2 will occur when the gas passes through the flask, since the temperature is decreased, sulphuric acid condensation occurs generating the whiteish gas inside the Kitasato as well as the sulphuric acid droplets condensate at the bottom. The remaining SO_3 will pass through the system generating the white smoke at the hose end. The source of the humidity issues could be poor drying or a water leak in heat exchangers, such as boilers, economisers or superheaters.

The presence of SO_3 and sulphuric acid entrainment are often evaluated at the absorption tower outlet, where the gas is expected to contain no SO_3, humidity or sulphuric acid entrainment, therefore, result 4 should be observed. If result 2 is observed, it may indicate absorption issues. Also, if result 3 is observed, it may indicate mist elimination problems.

A thorough inspection of the tower internals should be performed, evaluating uneven acid distribution, packing fouling with sulphate, tower gas velocity, plugging of downcomers, leaks and more if result 2 occurs. In case of result 3, empty seal cups, corrosion or plugging of drainpipes, warping or corrosion of the tubesheet, or gasket leak, amongst others may be the cause.

Stick test

The stick test indicates the health of the mist eliminators in the drying and absorption towers in a qualitative manner.

The test consists of inserting a wooden stick (preferably a bright coloured wood) using a nozzle that allows direct contact of the stick with the gas leaving the tower, downstream of the mist eliminators. Ideally it should be executed in a straight tube section at the tower outlet or at the vessel itself, but at a distance sufficient to guarantee good distribution of the gas flow. Clark recommends an exposure time of 30 to 60 seconds.

Any sulphuric acid particles that contact the stick will leave a dark spot on the surface of the wood; the type of spots and distribution may give some indication of the sources. It is important to take pictures of the stick before and after the test to compare what new spots have formed and what are natural wood stains.

Some possible results are listed below:

1. A stick that is completely clean or with few scattered spots indicates a perfect or great result.
2. A high number of scattered small spots indicate mist eliminator issues such as re-entrainment or gas preferential paths.
3. Part of the stick darkening indicates the presence of fine mist (common to absorption towers).
4. Total darkening of the stick indicates high concentrations of SO_3 (the non-absorbed SO_3 reacts with the residual humidity of the wood).
5. A totally or highly darkened and wet stick indicates a severe issue that must be addressed immediately.

Fig. 6 shows an example for each possible result listed above.

PHOTOS: CLARK SOLUTIONS

Fig. 6: From top to bottom: result 1 (perfect), result 1 (great), result 2, result 3, result 4, result 5.

Conclusion

People who visit a doctor frequently to check their health have more chances of identifying a sickness at an early stage and having treatment at a stage that minimises the consequences. Conversely, people who rarely visit a doctor may discover about a sickness too late. The same metaphor can be applied to sulphuric acid plants and the simple tests listed, since they serve as a doctor's appointment for the tower internals. Being able to notice issues at an early stage may bring some good results which translates into savings and plant safety.

When performing the tests listed for the first time, it is very important to consult with a specialised company, such as Clark Solutions, to gain the complete protocol of execution, not only the concise summary described in this article, granting a valid result and personnel safety. The company may also be able to provide a prognosis from the results and propose some solutions. ■

Sulphur: a critical component in soil and plant health

Sulphur is becoming an increasingly vital crop nutrient, due to a combination of lower sulphur deposition from the atmosphere, the increasing prevalence of high-analysis fertilizers and higher cropping intensity.

The sulphur cycle

Similar to nitrogen and phosphorus, sulphur follows a cycle (*Sulphur* 392 p. 16). This cycle illustrates:

- how sulphur moves between land, air and sea in different forms;
- key processes such as crop uptake, leaching and volatilisation;
- the microbial action which makes sulphur plant-available by changing it from organic to inorganic form.

Crops access and remove sulphur through their roots in sulphate form. It can also be taken up as sulphur dioxide gas.

Sulphur typically enters the soil solution by the mineralisation of organic matter. Every 1% of soil organic matter can supply around 1.4-2.3 kg of sulphur via mineralisation. Some soil microbes and plants immobilise (fix) sulphur while others mineralise (oxidise) it into sulphate. These mineralisation and immobilisation processes often occur simultaneously within soils as part of sulphur removal and replenishment. Because 95% of sulphur found in soils is associated with organic matter, low organic matter soils are typically sulphur deficient (*Sulphur* 392 p. 16).

From 2005 to 2014, the average amount of fertilizer sulphur used annually in global crop production was 10.6 million tonnes, with some 53% (5.6 million tonnes) of this applied to cereals[1]. However, recent calculations suggest that, on average, only one million tonne of the total sulphur applied in cereal crop production was subsequently recovered in the grain – suggesting a sulphur use efficiency (SUE) of around 18%[1]. Reasons for low SUE include sulphur:

- leaching;
- adsorption;
- retention in residues;
- immobilisation;
- failure to adhere to best agronomic practice, e.g. the 4Rs.

The fourth crop nutrient

Sulphur has become increasingly valued by the farm sector in recent years, to the extent that some now describe sulphur as 'the fourth crop nutrient' (*Fertilizer International* 497, p24).

Sulphur is present in all crops and plays an important metabolic role. It is essential for the formation of proteins, amino acids, vitamins and enzymes, and vital for photosynthesis, energy metabolism and carbohydrate production. Sulphur also contributes to the flavour and aroma of crops such as onions and can therefore influence the quality of farm produce.

Importantly, sulphur does not act alone as a plant nutrient, as it works in tandem with nitrogen to enable the formation of amino acids during protein synthesis. Sulphur is also part of the plant enzyme required for nitrogen uptake.

In crop nutrition, sulphur plays a critical role in early crop establishment and improves resistance to environmental stress. Deficiency stunts early plant growth, leading to later yield losses, and is exacerbated by the following conditions:

- light and sandy soils with low soil organic matter;
- sulphur leaching during high winter rainfall;
- low sulphate mobility during dry spring conditions;
- slower mineralisation at low temperatures;
- low input of organic matter and mineral sulphur;
- low atmospheric deposition of sulphur to soils.

The main signs of sulphur deficiency – pale green colouration, stunted growth and delayed maturity – mirror the symptoms of nitrogen deficiency. However, sulphur deficiency affects in newer growth, typically in the top leaves or whorl, while nitrogen deficiency shows up in the bottom leaves of the plant. A lack of sulphur in corn and wheat slows down photosynthesis and root/plant development as shown by a pale green colour and a lack of vigour.

Crops can typically remove between 15 to 30 kg of sulphur per hectare from soil. Root vegetables, onions and brassica, especially oilseed rape (canola), have a particularly high demand for sulphur. Pasture and other widely-grown crops such as coffee, corn, cotton, rice, soybean, sugarcane and wheat also require moderately high sulphur applications (Fig. 1). For these crop types, sulphur requirements can match or even exceed demand for phosphorus.

A bushel of corn, for example, removes 77 grams of sulphur in total – 36 grams in the grain and 41 grams in the stalk. That means 200 bushels of corn will remove sulphur at a rate of 38 kg/ha. This is equivalent to an actual removal rate of plant-available sulphate (SO_4) of 114 kg/ha (*Sulphur* 392, p. 16).

Increasing agricultural value

Sulphur is becoming an increasingly important crop nutrient due to three main factors (*Fertilizer International* 497, p.24):

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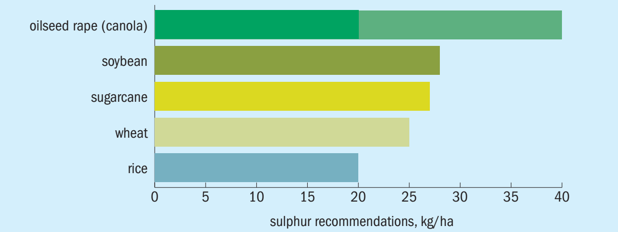
Fig. 1: **General sulphur recommendations for crops (kg S /ha)**



Source: TSI and others

- **Falling atmospheric deposition:** Soil sulphur deficiency, a relative rarity 20 years ago, is becoming more common. The deposition of sulphur dioxide emissions from the atmosphere used to guarantee that soils in many regions were automatically enriched and replenished with sulphur. This is no longer the case as increasingly stringent environmental regulations and the introduction of low-sulphur fuels have sharply cut emissions.
- **The prevalence of high-analysis fertilizers:** Farmers are continuing to switch to high-analysis products, containing little or no sulphur, at the expense of sulphur-rich, lower analysis products. This long-term buying trend has also put sulphur replenishment on a downward path.
- **Rising cropping intensity:** Improving crop yields are withdrawing ever larger amounts of sulphur from the field.

These three factors are, however, opening up opportunities for fertilizer producers. A number of leading manufacturers are capitalising on the value of sulphur by broadening their portfolios and supplying sulphur-enhanced fertilizers as premium products to meet growing market demand.

Global and regional consumption

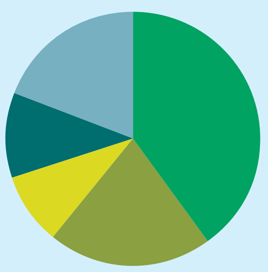
Accurate and up-to-date figures on sulphur fertilizer consumption are hard to come by. Despite this, the market is mainly divided between the following products, in order of popularity:

- ammonium sulphate;
- single superphosphate (SSP);
- sulphate of potash (SOP);
- NPS products;
- ammonium thiosulphate (ATS).

The total world market for sulphur-containing fertilizers was estimated at more than 66 million tonnes in 2015. On a nutrient basis this equates to global agricultural sulphur consumption of around 11.1 million tonnes. Sulphur consumption is greatest in Latin America (2.4 million tonnes), East Asia (2.1 million tonnes) and Southeast Asia and Oceania (1.8 million tonnes), with these three regions accounting for 57 percent of global agricultural sulphur usage[2].

However, worldwide agricultural consumption of sulphur could be closer to 13.3 million tonnes (Fig. 2), according to a first-of-its-kind assessment by the International Fertilizer Association (IFA)[3]. This volume is much higher than the frequently quoted estimate of 10-11 million tonnes. However, this latest tonnage is probably still an underestimate, suggests IFA, as it excludes data for some NPK+S products[3].

Fig. 2: **Agricultural sulphur consumption by product, 2015**



Source: IFA (2017)

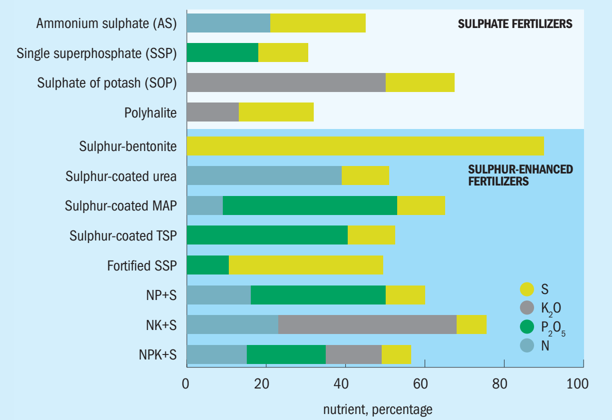
Market trends

The sulphur fertilizer market divides into two main categories – traditional sulphate fertilizers and sulphur-enhanced fertilizers. These have a wide range of nutrient compositions (Fig. 3).

Traditional sulphate fertilizers have long dominated global demand (*Fertilizer International* 476, p. 19). They include:

- **Single superphosphate (SSP)** is the second largest selling phosphate fertilizer on the market after diammonium phosphate (DAP). Consumption is concentrated in four main markets, China, Brazil, India and Australia, which collectively account for around 85% of total global demand. SSP is a low-analysis fertilizer with a nutrient content of around one-fifth (18-22% P_2O_5). Because of this, it tends to be consumed in the country of origin, and export volumes have declined due to increasing competition from more economic high-analysis phosphates. SSP consumption has contracted by almost a third in the past 20 years.
- **Ammonium sulphate (AS)** consumption, in contrast, is on the rise even though its nitrogen content is much lower than urea and ammonium nitrate. World supply (26.4 million tonnes) has been boosted by the massive growth of 'involuntary' production capacity in China. Consumption of AS is concentrated in the Americas (the US, Brazil, Mexico and Canada) and East and Southeast Asia (China, Indonesia, Vietnam and Malaysia). Turkey and Germany also offer sizeable markets for AS (*Fertilizer International* 469, p. 20). The use of AS in NPK blends has become increasingly popular as awareness of sulphur deficiency in soils has become more widespread. Rapid growth in world oilseed rape (canola) production has been a notable factor behind the rise in AS demand.
- **Sulphate of potash (SOP)** is valued as a chloride-free source of potash for lucrative cash crops such as tobacco, tree nuts and citrus fruits. Agricultural consumption is 7-8 million tonnes currently. China accounts for more than half of global use and has been responsible for much of the expansion in SOP demand globally in recent years. North America and Europe are also sizable markets accounting for some 60% of demand outside of China (Fertilizer International 475, p. 49). Global demand is supply-constrained meaning that SOP trades at a premium.

Fig. 3: **Nutrient content (NPK+S) of selected sulphate and sulphur-enhanced fertilizers**



Source: Various

- **Sulphate of potash magnesia (SOPM)** global demand has grown strongly in recent years. The market for SOPM, similar to SOP and SSP, is highly concentrated with just four countries, China, the US, Canada and Germany, accounting for the lion's share of consumption. Production is also mainly located in three countries, China, the US and Germany.
- **Ammonium phosphate sulphate (APS)**, a fertilizer with a 60% ammonium sulphate and 40% MAP composition, is a commonly produced grade of NP+S fertilizer (16-20-0-14S). It is directly applied to forage crops in many countries, particularly legumes, and is also a popular choice of fertilizer for small grains and oilseed rape (canola). The global sulphur fertilizer market is still dominated by AS, SSP and SOP, with these three products combined being responsible for 70% of agricultural sulphur consumption (Fig. 2).

Sulphur-enhanced fertilizers

Crop requirements for sulphur were projected to exceed 24 million tonnes by 2020. Fertilizer producers have reacted to this widening demand gap by developing sulphur-enhanced fertilizers. Many of these premium products are manufactured by analysis fertilizers, either within granules or as an external coating. Introducing a liquid sulphur spray to urea, TSP, MAP or DAP during drum or pan granulation, for example, results in NPS products with a 5-20% elemental sulphur content.

Sulphur-enhanced fertilizers combine nutrient availability with high use-efficiency, and also have good storage and handling properties. Examples include:

- sulphur bentonite;
- sulphur-coated urea, MAP or TSP;
- sulphur-enriched SSP;
- sulphur-enhanced MAP enriched with sulphate.

Sulphur-enriched SSP is popular in countries such as New Zealand and can contain twice as much sulphur as ordinary SSP. Added elemental sulphur complements SSP's existing sulphate content and helps meet crop needs during the whole growing season by providing both immediate and reserve stores of sulphur. This makes it particularly suitable for applications in areas with high leaching losses.

Controlled release fertilizers (CRFs) can be produced by coating highly-soluble nutrients with relatively insoluble elemental sulphur. **Sulphur-coated urea (SCU)**, for example, combines 77-82% urea (36-38% N) with a 14-20% sulphur coating. SCU is suitable for multiple nitrogen applications on sandy soils under high rainfall or irrigation conditions. It is marketed as a CRF for grass forage, turf, sugarcane, pineapple, cranberries, strawberries and rice.

To be of value to crops as a nutrient, the elemental sulphur (S8) present in sulphur-enhanced fertilizers firstly needs to be oxidised into plant-available sulphate by thiobacillus soil bacteria. This process requires the availability of oxygen and moisture and only occurs within a certain temperature range.

Fine elemental sulphur (40-150 microns) can be combined with 5-10% swelling clay to form sulphur-bentonite pastilles. The minor clay component promotes microbial conversion into sulphate early in the growing season by dispersing and releasing sulphur particles into the soil. This helps guarantee the supply of sulphur throughout the season and minimises leaching losses. Sulphur-bentonite is widely-used to treat sulphur deficiency in the US and India and is suitable for blending as well as direct application.

Liquid sulphur products

Liquid sulphur products – thiosulphates – are also favoured in some countries and regions, particularly in North America and Europe.

Thiosulphates offer sulphur in both immediately plant-available form and in slower release form available to plants over a longer period of time. Thiosulphates also have a modest acidification effect, benefitting crops growing on alkaline (calcareous) soils. Providing sulphur to crops by applying thiosulphates offers a number of specific benefits:

- enhances crop protein and chlorophyll content;
- assists the synthesis and functioning of enzymes in the plant;
- optimises fertilizer efficiency by stabilising nitrogen;
- improves availability of nutrients in the soil, particularly phosphorus and micronutrients and their uptake by the crop;
- energy efficient assimilation in the plant;
- provides prolonged sulphur nutrition;
- a controlled and localised pH adjustment effect in the soil. ■

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