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March | April 2025

SULPHUR

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Lithium production

Changing battery chemistries mean more acid for lithium mining

Variable SO_2 feeds

Using regenerative scrubbing in acid plants

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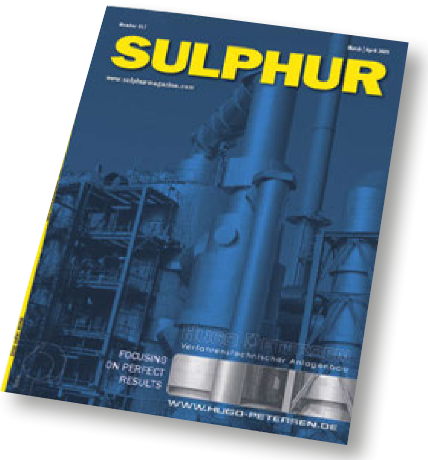
REGULARS



Sulphur prices soaring

The past few weeks have seen sulphur prices spiking after a steady rise since 3Q 2024. At time of writing, delivered prices to a variety of locations were around $280/t c.fr, their highest level since mid-2022 when the price of commodities of all kinds jumped in the wake of the Russian invasion of Ukraine and subsequent sanctions. Steady buying from Indonesia and China, the two largest importers of sulphur, appears to have supported the market, in China's case mainly for phosphate production as well as a variety of industrial processes, and in Indonesia's case to feed the high pressure acid leach (HPAL) plants that are producing nickel for the battery and stainless steel industries. Although Chinese buying has dropped off slightly since Lunar New Year, and demand has also slackened in India, Indonesia's appetite continues unabated, having tripled its nickel production since the start of the decade to become the world's largest producer, representing 60% of global supply in 2024.

> **"Global trade disruptions may also once again be playing into markets..."**

Indeed, Indonesia has arguably crashed the world nickel market, halving prices since 2022, and is starting to become a victim of its own success, with some indications that the Indonesian government is considering drastically reducing nickel mine quotas this year, possibly by as much as 45%, which could have a devastating knock-on impact upon sulphur and sulphuric acid markets. In the meantime, though, it is stocking up on sulphur.

Global trade disruptions may also once again be playing into markets – the US has imposed 25% tariffs on goods from Canada, from where it takes a lot of its sulphur requirement. There is also a 10% tariff on oil and related products from Canada, which may lead to lower refinery runs in the US and a hit to domestic sulphur production. As the US is mostly set up to take molten sulphur from Canada rather than importing bulk granules (with the exception of Mosaic's sulphur remelter at New Wales), there is probably no alternative for US consumers except to pay higher prices.

High phosphate prices are also helping support sulphur prices, with markets tight, as we note on pages 24-25 of this issue, due to ongoing export restrictions from China. Chinese port stocks of sulphur are at high levels and Chinese domestic supply of sulphur and acid continues to increase, but overall the sulphur market remains in deficit, with the metals and phosphate fertilizer industries continuing to demand increasing quantities. Some stock drawdowns in Kazakhstan and Saudi Arabia have mitigated market shortages, but the current price rally shows that there are clearly supply shortages emerging.

In the longer term, new supply in the Middle East and China will offset any shortfall in the market, and if Indonesia really does rein in its nickel overproduction, then we may also see demand contract there, but in the meantime these are good times to be selling sulphur.

Richard Hands, Editor

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Price Trends

SULPHUR

Global sulphur benchmarks rallied at the end of February, underpinned by strong demand in Indonesia and stock drawdowns in China as fresh European sanctions on Russia targeted the port of Ust-Luga. Chinese buyers paid up to $225t/t c.fr for a cargo, with unconfirmed rumours of business at even higher levels. However, delivered prices still lag domestic port spot prices in China, which are now assessed at a delivered-price equivalent of around $242/t c.fr. China's delivered sulphur price jumped significantly as port inventories declined, and new arrivals were limited. Only two new cargoes were reported in the last week of February, one from a mainstream source into southern China at $205/t c.fr, and the second at $225/t c.fr by a phosphate producer for the Yangtze River. The sulphur port spot transaction price is reported at around 2,040-2,050 yuan/t FCA ($281-283/t), with the low-end up $26/t and high-end up $25/t compared with previous settlements. That port price indicates delivered values at around $242/t c.fr, which is $17/t higher than the import price on the Yangtze. Phosphate producers need to purchase more sulphur to meet the increased buying activity in northeastern market and the improving spring application season demand in northern China. Still, market sales availability is limited, as most port tonnes are held by traders instead of end-users, while traders are selling limited quantities now to push prices higher. Chinese total port inventory dropped to 1.89 million tonnes by 26 February 2025. The quantity at Yangtze river ports declined 59,000 tonnes to 633,000 tonnes, while Dafeng port inventory decreased 20,000 tonnes to 450,000 tonnes.

Indonesia has been the focus of market attention since the start of the year as other delivered markets such as China and India have slowed down their purchasing. Four new purchases were reported by Indonesia at the end of February, and demand there was cited by most participants as the main factor pushing global sulphur prices higher. Sales ranging from $202/t c.fr to as high as $225/t c.fr were reported and the price was assessed at $215-220/t c.fr. A sale believed to be by Shell at $202/t c.fr was not deemed repeatable, and Total was linked to a sale at $216/t c.fr. Aramco was suggested as the seller of two further cargoes to Huayou, with at least one at $220/t c.fr. PT Lygend closed a tender on 26 February for another cargo for 50,000 tonnes, although no offers were reported at the time of writing and no award suggested.

Brazil stepped back into the market after a quiet start to the year with CMOC taking 40,000 tonnes for April arrival at a price close to $225/t c.fr. After limited activity since the start of the year, the delivered price into Brazil was assessed significantly higher based on the CMOC tender as well as rising prices globally. Offers in CMOC's tender were reported as high as $230-240/t c.fr, although these are understood to have been rejected. Mosaic last bought at $190/t c.fr, and most participants had not expected prices to punch higher so swiftly.

In the Middle East, Qatar's Muntajat awarded its monthly sales tender for 35,000 tonnes at $212/t f.o.b., with bids as high as $210/t f.o.b. rejected. QatarEnergy posted its March monthly sales price at $202/t f.o.b., up $30/t from February. This new QSP reflects delivered levels to China in the low-$220s/t c.fr at current freight rates. This is the highest price from Qatar since July 2022, when prices spiked following the Russia invasion. The benchmark has advanced $36/t since start of the year. ADNOC's recent shift in sulphur trading strategy away from traders and towards moving its own tonnes was sapping liquidity from the forward market, some suggested, while one trader said there was no longer a forward market for sulphur at all, with the market essentially dominated by two major Middle East producers.

One element of the sixteenth round of European Union sanctions on Russia timed to coincide with the third anniversary of the full-scale invasion of Ukraine was a full transaction ban on three Russian ports, including Ust-Luga, which exports large volumes of Kazakh and Russian sulphur. Opinions on the impact of the fresh sanctions are mixed and the outcome is not yet clear, although they are EU not US sanctions, and US companies such as Trammo may well be unaffected. Should there be an impact on export volumes from Ust-Luga, Morocco may feel the pinch as a major buyer of Baltic tonnes, and Brazil also takes tonnes from the region.

Baltic prices were assessed unchanged, although there is a considerable degree of unease about trade from the region following the EU's fresh sanctions on Russia this week that named Ust-Luga as a banned port. The Baltic sulphur price is assessed at $165-175/t f.o.b.

SULPHURIC ACID

Sulphuric prices declined in February in delivered markets due to a slowdown in buying activity, aided by a decline in freight rates. Weakening demand has also placed pressure on European pricing, while benchmarks have remained stable in Asia. Tight availability is still present across exporting regions but signs of this situation easing have begun to materialise.

BHP's latest tender for 20,000-30,000 tonnes of acid for arrival during Q2 in February in Chile has signalled a bearish trend in acid prices, which have declined from $150-155/t to $140-150/t c.fr. The tender was said to have been awarded in the low to mid $140s/t, according to multiple sources. Limited available storage capacity, commitments to new annual contracts and ocean swells have slowed buying activity in 2025. Additionally, lower freight rates have enabled price declines, while seasonal rough seas have restricted spot deals. Similar market conditions are expected to continue until around March, according to local market participants. For the full year of 2024, Chilean acid imports fell 3.5% to 3.62 million t/a compared to 3.75 million t/a in the same 12 months of 2023.

In the US Gulf, prices decreased to $135-140/t c.fr after two months at $140-145/t, as weak import demand continued and a bearish sentiment settled in the market. Demand has been weak on the back of a price gap between acid imports and local sulphur burnt acid. The US prefers burning sulphur than taking import acid cargoes as it remains the more attractive of the two options.

The delivered price in Brazil also fell from $165-175/t to $130-140/t c.fr. Buying activity in the market has remained muted, and Brazilian imports fell by 27% year on year in January to 53,690 tonnes. Local availability is set to increase as Unigel announced in early 2025 that it will begin operations at its 450,000 t/a sulphuric acid plant by September 2025. Additionally, Petrobras commissioned its new atmospheric emissions abatement unit in late 2024, which converts sulphur oxide into sulphuric acid, adding 200,000 t/a of acid supply. Increased local supply will limit import requirements.

PHOTO: MAUINOW1/ISTOCKPHOTO

Sulphur mounds at Vancouver, BC

In India, prices declined in the first week of February from $105-110/t to $100-105/t c.fr as a slowdown in buying activity persists. Acid availability will increase in 2025 with the start-up of the 1.5 million t/a capacity Adani Copper smelter. Paradeep Phosphates (PPL) is also expected to commence sulphuric acid production in 2025 H_2, increasing acid supply by 500,000 t/a. Still, the company has indicated plans to expand its phosphoric acid production that would require significant sulphuric acid volumes absorbing some of the supply increase.

An uptick in activity towards the end of 2024, amid limited availability, pushed acid prices up in China, Japan, and S. Korea, and they remained stable at $50-55/t f.o.b. in February 2025. The local Chinese market is still firm, but the pricing environment started to decline in February to an equivalent of $61/t (vs. $64/t in late December).

Weaker traded acid demand in Atlantic markets is placing pressure on prices at Europe f.o.b., with prices falling from $110-120/t to $95-105/t, according to deals recently reported in Brazil and Chile. A lack of molten sulphur coupled with a copper/zinc concentrate shortage could potentially keep European prices firmer, but Morocco's pullback of import requirements will negatively impact prices. Morocco's OCP, which had returned to buying acid last year, has remained absent from the spot market and sources said this has impacted the sentiment in Europe. Morocco is estimated to have imported 1.9-2.0 million t/a of acid in 2024, with requirements expected to fall to 1.1 million t/a in 2025. Multiple tenders in the region and spot deals indicated lower prices and provided the market with a bearish price signal, while freight rates also declined from key supplying regions. Seasonal rough seas in recent weeks had already dampened any spot demand in the region, while buyers were also sufficiently stocked, leaving less room for more spot purchases.

Prices remained relatively stable in Asia, however. There were some indications that buying in Indonesia is likely to begin in March. Indonesian c.fr prices are in the $90s/t but indications are that they would dip to the $80s/t. Furthermore, negotiations for quarterly contracts in Japan/South Korea and China are yet to begin, with this likely to restart towards the end of March. Prices in China were unchanged at $50-55/t f.o.b. in February. The price range in Japan/South Korea was assessed flat at $10-55/t f.o.b. Separately, Glencore-managed Pasar announced its decision to place its Leyte copper smelter site into care and maintenance due to deteriorating market conditions. This move is set to remove at least 500,000 t/a of acid from the market, with the impact likely felt by producers in Asia.

Price Indications

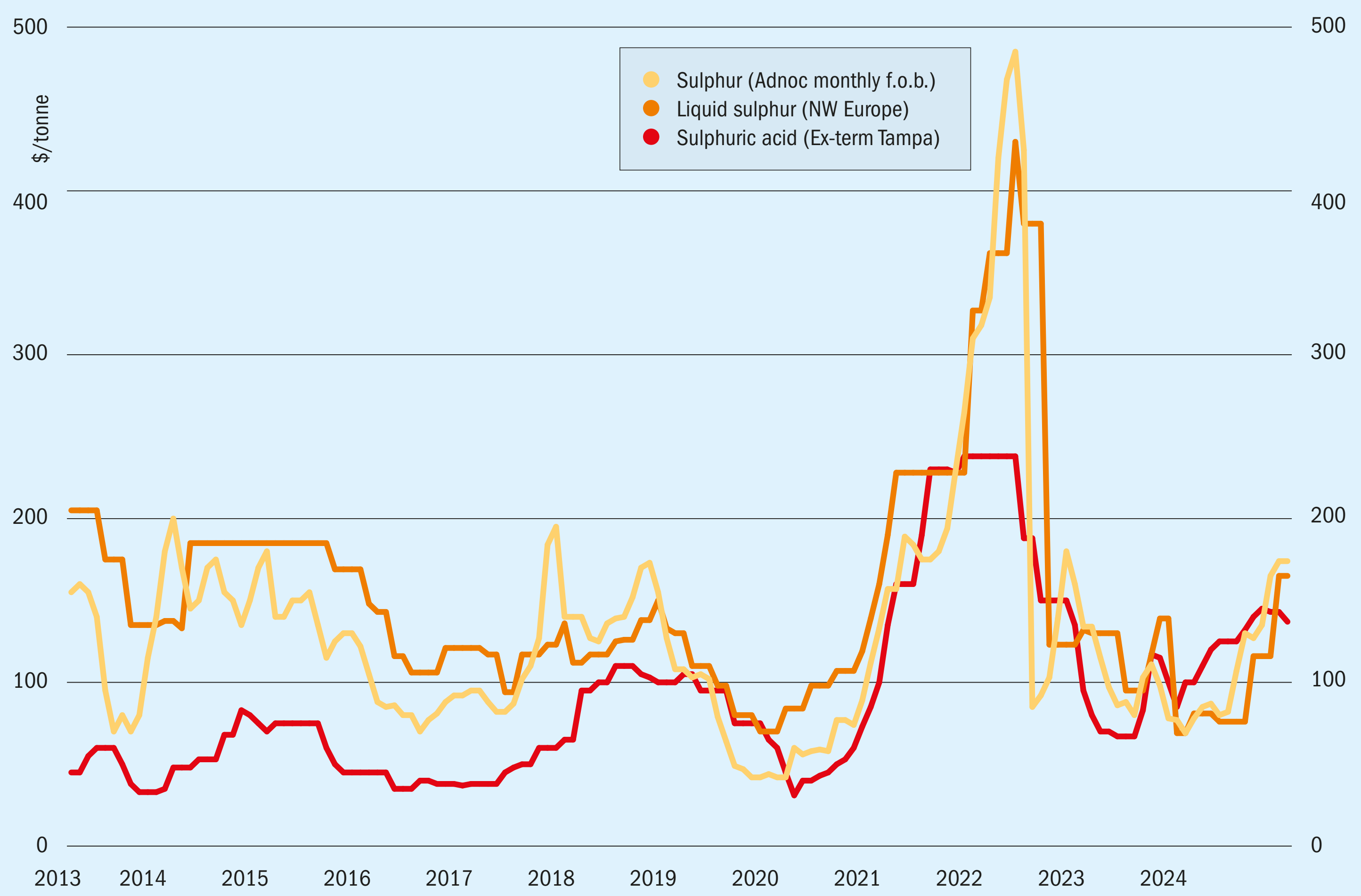
Table 1: **Recent sulphur prices, major markets**

Cash equivalent	October	November	December	January	February
Sulphur, bulk ($/t)					
Adnoc monthly contract	127	135	165	174	174
China c.fr spot	154	184	184	184	223
Liquid sulphur ($/t)					
Tampa f.o.b. contract	116	116	116	165	165
NW Europe c.fr	193	193	193	214	214
Sulphuric acid ($/t)					
US Gulf spot	140	145	143	143	137

Source: various

Market Outlook

Historical price trends $/tonne



Source: BCInsight

SULPHUR

- Sulphur prices have been revised higher in the latest forecast after supply from the Middle East was lower than expected in February, and buyers with uncovered demand were forced to chase prices upwards. UAE sulphur exports normally fall at the start of the year due to scheduled maintenance, but sales in February this year were 200,000 tonnes short of what is typical. Prices may climb more than expected as buyers scramble to cover their shorts. If supply is slower to return than currently anticipated, momentum may push prices even higher in the short term.
- Prices are expected to ease around the start of Q2 as supply returns to normal and this will coincide with Kazakhstan pulling back its exports, as its inventory will be exhausted. One element of the sixteenth round of EU sanctions on Russia was a full transaction ban on three Russian ports, including Ust-Luga, which exports large volumes of Kazakh and Russian sulphur.
- Opinions on the impact of the fresh sanctions are mixed, and the outcome is not yet clear, although they are EU not US sanctions, and US companies such as Trammo may well be unaffected. Should there be an impact on export volumes from Ust-Luga, Morocco may feel the pinch as a major buyer of Baltic tonnes, and Brazil also takes tonnes from the region.

SULPHURIC ACID

- Prices in the sulphuric acid market, which have generally increased since the start of 2024, are expected to decline as 2025 Q1 progresses. Prices are now forecast to hold at similar levels to those seen in February. The declines in global prices will be shaped in pace and timing by fluctuations in the supply/demand landscape, but expected decreases could be more moderate or materialise later than expected depending on supply/demand dynamics.
- Availability in Europe, while still anticipated to return in 2025 Q1, has not yet materialised. The lack of spot market availability pushed prices briefly to $110-120/t f.o.b., the highest since September 2022, before falling back in late February on lower demand from Morocco.
- Purchases of acid in Chile have been limited as buyers remain largely unable to take on spot volumes. The seasonal rough seas have also hampered new business. Local market participants expect similar conditions to continue into early March. The price is forecast to continue decreasing, stabilising at $148/t c.fr for May, June and July.
- China prices fell as traders cleared inventory ahead of New Year celebrations. The price narrowed to its current range of $50-55/t f.o.b. having adjusted to lower inventory levels.
- Local production and availability in India and Indonesia have increased and are expected to increase further. An increase in local availability could limit import requirements, with Adani's smelter expected to start operations by 2025 H1. Paradeep Phosphates Ltd. (PPL) is also expected to commission a 500,000 t/a sulphuric acid plant by 2025 Q2.

Sulphur Industry News

UNITED STATES

Sulphur supply agreed for battery manufacturing

PHOTO: LYTEN

Lyten's battery plant in California

Lithium sulphur battery manufacturer Lyten has signed agreements with California Sulphur Company, at the Port of Los Angeles, and a Port of Stockton company to supply US domestically sourced, industrial-grade sulphur to Lyten's manufacturing facilities in San Jose, CA, San Leandro, CA, and its recently announced Reno, NV, "gigafactory".

Dan Cook, Lyten Co-Founder and CEO stated, "The US needs an alternative to lithium-ion batteries. Batteries are critical to the functioning of our energy grid, powering satellites, supporting our military, ensuring competitiveness of US companies, and powering new forms of transportation. Today, the supply of nearly every lithium-ion battery is controlled by a single country, creating an enormous vulnerability for the US. Lyten's Lithium-Sulphur batteries use local materials, are fully manufactured in the US, and are cost competitive because of low-cost sulphur."

The use of low-cost sulphur creates a battery cathode that is 40% lighter weight than lithium-ion, which requires nickel, manganese and cobalt (NMC), and 70% lighter weight than Lithium Iron Phosphate (LFP), which currently lead the market.

Celina Mikolajczak, Lyten Chief Battery Technology Officer, said: "In every industry, weight is critically important. In satellites and drones, we can remove kilograms of weight that directly translates into more payload. In vehicles, we can remove hundreds of kilograms of weight that improves cost, safety, and range while reducing the impact on transportation infrastructure. In battery energy storage systems, we can literally remove tons of weight, dramatically simplifying installation and reducing infrastructure cost. In our observation, electrifying everything requires the lighter battery weights we are achieving with lithium-sulphur."

Lyten signed a $650 million loan in December 2024 with the Export Import Bank of the US (EXIM) to fund the scale up and delivery of its Li-S batteries energy storage systems (BESS). Additionally, in 2024, Lyten announced its integration into Chrysler's Halcyon Concept EV, plans to integrate lithium-sulphur into AEVEX Aerospace's unmanned aerial vehicles (UAVs), and the selection of its battereis for demonstration on-orbit aboard the International Space Station (ISS), scheduled for launch later in 2025. ■

FRANCE

TotalEnergies to decarbonise its refineries in Northern Europe

TotalEnergies has signed agreements with Air Liquide to develop two projects in the Netherlands for the production and delivery of some 45,000 t/a of green hydrogen produced using renewable power, generated mostly by the OranjeWind offshore wind farm, developed by TotalEnergies (50%) and RWE (50%). These projects will cut CO_2 emissions from TotalEnergies' refineries in Belgium and the Netherlands by up to 450,000 t/a and contribute to the European renewable energy targets in transport.

The two companies have signed an agreement to set up a 50-50 joint venture to build and operate a 250 MW electrolyser near the Zeeland refinery. This project will enable the production of up to 30,000 t/a of green hydrogen, most of which will be delivered to Zeeland's platform. The electrolyser will be commissioned in 2029 and will cut the site's CO_2 emissions by up to 300,000 t/a. This project represents a global investment of around €600 million for both partners and has made requests for support under European and national subsidy programs. Project funding will also be sought by the partners.

In addition, as part of Air Liquide's 200 MW ELYgator electrolyser project in Maasvlakte, TotalEnergies has signed a tolling agreement for 130 MW to be dedicated to the production of 15,000 t/a of green hydrogen for TotalEnergies in Antwerp. Under this agreement, TotalEnergies will supply the renewable electrons produced by the OranjeWind project to Air Liquide to be transformed into green hydrogen. The project is expected to be operational by the end of 2027 and will reduce CO_2 emissions at the Antwerp site by up to 150,000 t/a.

"Following the first partnership agreement with Air Liquide to supply the Normandy refinery with green hydrogen, and the agreements to supply the Grandpuits and La Mède biorefineries with renewable hydrogen, the partnership with Air Liquide… marks a new step in TotalEnergies' ambition to decarbonise the hydrogen consumed by its refineries in Europe by 2030", said Vincent Stoquart, President, Refining & Chemicals at TotalEnergies.

IRAQ

Gas treatment plant for Basra

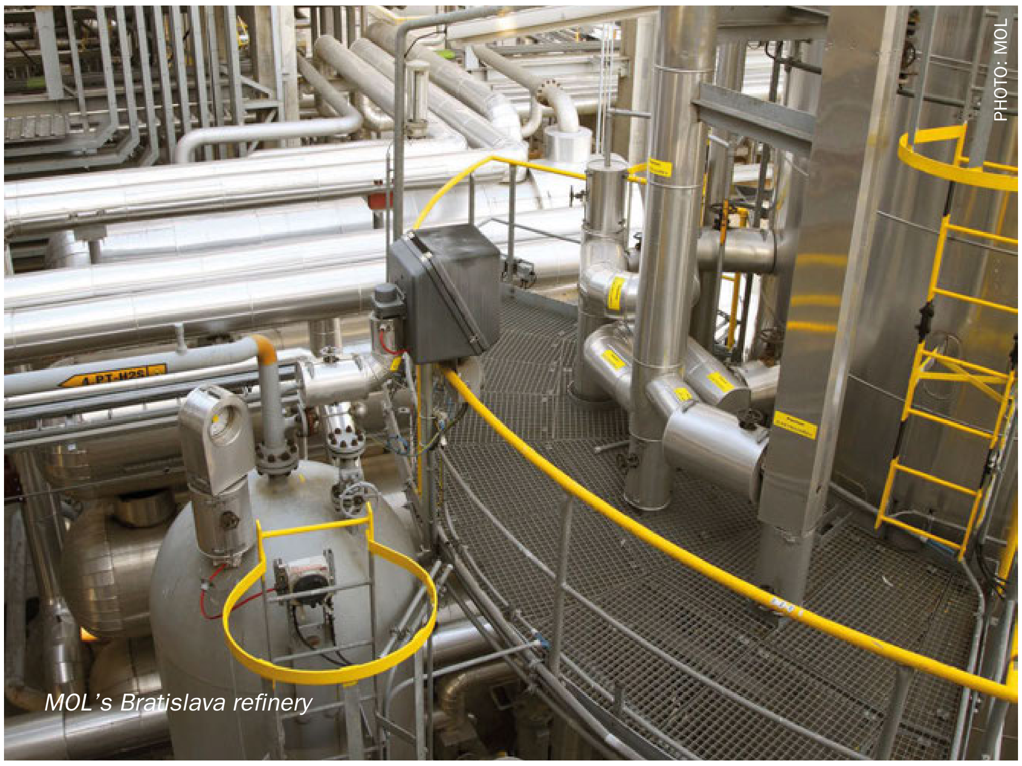
TotalEnergies and its partners Basra Oil Company and QatarEnergy have begun construction works at ArtawiGas25, a processing facility for the associated gas from the Ratawi field, located in the Basra region. The facility, part of the Gas Growth Integrated Project (GGIP), represents an investment of around $250 million and will process 50 million scf/d of gas which would previously have been flared. The gas will supply local power plants, covering the demand of approximately 200,000 households in the Basra region. The GGIP project is a $10 billion project designed to enhance the development of Iraq's natural resources and improve the country's electricity supply. It includes a large-scale gas processing plant, with a first phase of 300 million scf/d that will recover gas being flared on three oil fields and supply gas to 1.5 GW of power generation capacity.

HUNGARY

MOL co-produces HVO and SAF

MOL Group has produced a diesel fuel containing hydrotreated vegetable oil (HVO), and sustainable aviation fuel (SAF) at the Slovnaft refinery in Bratislava. The HVO was produced using oil from cashew nut shells and the biocomponent produced this way was processed together with crude oil. MOL has already been using co-processing at its Danube Refinery in Százhalombatta for some years, mixing plant residues, as the bio and fossil fuel components are processed simultaneously during production. The SAF at Bratislava was also produced via co-processing, using partially refined cooking oil together with more traditional raw materials.

"We are technologically ready to produce biodiesel of vegetable origin as well as sustainable aviation fuel. This could open a new chapter in the sustainable efforts of MOL Group: we offer our customers an increasing variety and quantity of fuels, thus contributing to the smart energy transition as well," said Csaba Zsótér, Senior Vice President, Fuels at MOL Group.



MOL's Bratislava refinery

RUSSIA

Attack on sour gas plant

Russian media reports suggest that a large scale Ukrainian drone strike on February 3rd attacked a number of oil and gas processing facilities, including Gazprom's Astrakhan Gas Processing Plant. Video of the site showing fires burning were posted to social media. Astrakhan is one of the largest sulphur producing sites in Russia, with an output of around 3.5 million t/a in 2024. The Moscow Times reported that production had been shut down at the site, and would likely remain so for "several months".

UNTIED ARAB EMIRATES

Tender launched for SARB expansion

The Abu Dhabi National Oil Company (ADNOC) has launched a tender for the expansion of offshore gas production at its Satah Al Razboot (SARB) field, part of the Emirate's huge Ghasha concession. The scope of work will include the engineering, procurement, and construction (EPC) of at least two wellhead platforms with multiple related facilities and the installation of a 24" subsea gas pipeline to new inlet facilities at Das Island. The project will also include brownfield tie-ins at Al Qatia, Bu Sikeen Islands, Das and Zirku and Arzanah Islands.

Gas-based projects worth upwards of $25 billion are currently in the execution phase in Abu Dhabi, with several other key gas developments under way, including the Umm Shaif gas cap, Bab gas cap, Al Dhafra and the Ruwais Diyab unconventional developments which aim to significantly boost Abu Dhabi's gas production capacity over the coming years.

CHINA

Topsoe chosen as technology provider for SAF project in Guangxi

Topsoe has been selected by Guangxi Free Trade Zone Chuangui Lingang New Energy Co., Ltd to deliver technology and services to produce sustainable aviation fuels (SAF) and renewable diesel.

The agreement represents Topsoe's second SAF project in China, following its first agreement in April 2024. The plant will be located in Guangxi, China, and reached final investment decision (FID) in December 2024, with operations due to begin in December 2026. Once operational and at full capacity, the plant expects to process 300,000 t/a of feedstock into SAF and renewable diesel per year.

Elena Scaltritti, Chief Commercial Officer at Topsoe, said: "Our partnership with Chuangui New Energy company is an important milestone for the growth of Topsoe's SAF offering in China and reflects our commitment to scale SAF production across the globe. We look forward to supporting critical energy transitional industries in China, such as Chuangui New Energy company, and deliver on its decarbonisation goals."

POLAND

Grupa Azoty to produce sulphur enhanced fertilizer

Grupa Azoty SA is set to begin producing its new multi-component fertilizer – POLIFOSKA Multi S –at its Police site in Poland. This launch marks the latest addition to the company's fertilizer portfolio, joining the likes of megAN (a high-granule ammonium nitrate fertilizer), RSM OPTIMA (a nitrate-urea solution with a distinctive light blue colour for easy product origin identification), and eNpluS (an ammonium fertilizer enriched with sulphur and calcium). POLIFOSKA Multi-S is designed with readily soluble and plant-available nutrients: 7% nitrogen in ammoniacal form, 10% phosphorus, 20% potassium, 5% calcium, 1% magnesium, and 23% sulphur in sulphate form. It is also enriched with silicon. Thanks to its excellent water solubility, the nutrients are rapidly delivered to the roots, supporting plant development from the very start of the growing season.

"Expanding our product range this time with a multi-component fertilizer, we have formulated POLIFOSKA Multi S to be highly efficient. Its balanced nutrient composition not only promotes proper plant growth and development but also enhances crop yield quality—with notable economic benefits. I am convinced that we are introducing a fertilizer that will soon become one of the flagship products in Grupa Azoty Police's range," commented Hubert Kamola, Vice President of the Management Board of Grupa Azoty.

KAZAKHSTAN

TCO starts up future growth project

Chevron says that its 50% owned affiliate Tengizchevroil LLP (TCO) has started oil production at its Future Growth Project (FGP) located at the Tengiz oil field in Kazakhstan. FGP is the third processing plant in operation at the Tengiz oil field, which expands sour gas injection capability and is expected to ramp up output to 1 million bbl/d. This milestone follows the completion of the Wellhead Pressure Management Project (WPMP) in 2024, which is designed to optimise the field and processing plants. The FGP expansion aims to increase crude oil production by 260,000 bbl/d at full capacity.

"First oil at the Future Growth Project is the latest in a series of development milestones, including in the Gulf of Mexico and the Permian, that are expected to significantly increase free cash flow to the company and deliver value for Chevron shareholders," said Mark Nelson, Chevron vice chairman.

The FGP and WPMP projects together installed power systems at Tengiz with five Frame 9 gas turbine generators, added four large compression trains with additional pumping capacity, installed a new centralised control centre and enhanced sour gas handling and reinjection to the field for long-term pressure maintenance. Tengizchevroil LLP is 50% owned by Chevron; 20% by KazMunayGas; 25% by ExxonMobil; and 5% by Lukoil.

SAUDI ARABIA

NextChem awarded refinery SRU improvement contract

Maire Group says that its NextChem (Sustainable Technology Solutions) subsidiary has been awarded a three-year contract by Saudi Aramco Total Refining and Petrochemical (SATORP) – a joint venture between Saudi Aramco and TotalEnergies – to provide engineering and technology services related to the sulphur recovery complex of SATORP's refinery in Jubail, Saudi Arabia. NextChem will provide process and engineering advisory services to enhance performance, support operational troubleshooting, and improve energy efficiency and the carbon footprint of the three units (sulphur recovery unit, amine regeneration unit and sour water stripper) which comprise the sulphur recovery complex. The services will also include recommendations for capital investment opportunities, design enhancements, and technology improvements.

Alessandro Bernini, CEO of Maire, commented: "This collaboration marks a significant milestone in our ongoing efforts to drive sustainability and efficiency in the refining industry. This agreement not only strengthens our relationship with SATORP, after Tecnimont's multibillion-dollar petrochemical expansion project awarded in June 2023 – the so called Amiral project – but also underscores our commitment to delivering cutting-edge engineering and technology solutions that reduce environmental impact."

SATORP is the largest refinery in Saudi Arabia, with a capacity of 465,000 bbl/d of refined products.

KUWAIT

Bids invited for gas sweetening facility

Kuwait's state owned Kuwait Oil Company (KOC) has issued a tender for companies to bid on construction of the second phase of its gas sweetening facility at booster station BS 171 in West Kuwait. Thirty-two companies have been pre-qualified to bid for the $390 million engineering procurement and construction (EPC) contract for the project. Phase II will involve the construction of two processing trains, each with a capacity to produce 60 million scf/d of sales gas from sour gas with an H2S content of 4%. Sulphur recovery from the project will come from two separate 100 t/d trains with a total capacity of 65,000 t/a of molten sulphur.

Contract expected on oil project

Spetco's contract with the Kuwait Oil Company (KOC) to install depletion compression systems and sulphur recovery units (SRUs) is said to be awaiting final approval. The $460 million project will upgrade two key facilities in North Kuwait, and Spetco says that it expects project execution will start quickly after final approval. The project involves installing new units at the Early Production Facility 50 (EPF-50) and Jurassic Production Facility 3 (JPF-3) using uses a build-own-operate-transfer (BOOT) contract model. The contract was originally tendered in 2023, but scope changes meant that the deadline has been extended several times.

The aim of the work is to sustain production from the facilities by installing compression systems and SRUs.The first part focuses on installing a new medium-pressure (MP) compression system and SRU at EPF-50. The second part focused on installing a new MP compression system and SRU at JPF-3. The EPF-50 and JPF-3 facilities receive sour wet hydrocarbons reservoir fluids through flowline gathering networks and trunk lines. Crude, gas and water are separated in a separation section currently receiving well fluid at 1,100 psig, and the crude is stabilised to export after desalting. The separation section consists of HP, MP and low-pressure (LP) separators in series. MP and LP gases are compressed to HP and combined with gas from HP separators. The gas is then treated in gas sweetening and dehydration units before being exported via pipeline. As the well fluid pressure depletes to MP, the combined feed from the inlet production headers and test header will be routed through a crude pre-heater to the new MP separator, which operates at about 425-450 psig. The new compressors will compress the gas from MP to HP.

The EPF-50 facility can currently process 200 million scf/d of gas, 50,000 bbl/d of oil and 130 t/d of sulphur. Originally, the upgrade project was expected to increase the volume of sulphur it can process to 270-310 t/d, but after the proposed changes to the scope, the capacity is now expected to be larger. The JPF-3 facility can currently process 150 million scf/d of gas, 50,000 bbl/d of oil and 200 t/d of sulphur. Originally, the planned upgrade was expected to increase the volume of gas that the facility can process to 240 million scf/d and the volume of sulphur to 440 t/d, but due to the scope changes, the capacity of JPF-3 will now be increased by more than the volumes outlined.

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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 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48

INDONESIA

Merdeka Battery to build new HPAL plant

PT Huayue Nickel Cobalt's site at Morowali.

PHOTO: PT HUAYUE NICKEL COBALT

Indonesian nickel miner Merdeka Battery Materials (MBMA) and partners have signed definitive agreements to construct a high-pressure acid leach (HPAL) plant on the Morowali industrial park, Sulawesi. The unit will have a nameplate capacity of 90,000 t/a of contained nickel in mixed hydroxide precipitate (MHP). PT Sulawesi Nickel Cobalt (SLNC) will construct and operate the plant adjacent to the existing HPAL plant operated by PT Huayue Nickel Cobalt (HNC). SLNC will source and process laterite nickel ore through a 20 year commercial agreement with MBMA's SCM mine, starting from the commissioning date. An ore preparation plant will be built at the SCM mine to enable ore transportation via pipeline to the SLNC processing plant at IMIP. The total combined investment for constructing SLNC (including interest incurred during construction) is expected to be approximately $1.8 billion according to Merdeka. Construction of the project commenced in January 2025 and is expected to reach commissioning stage within 18 months.

Teddy Oetomo, President Director of MBMA, said: "Expanding our downstream processing capabilities is essential to our strategy for maximising the value of our extensive nickel resources. The SLNC partnership, supported by competitively priced debt financing from leading domestic and regional banks, represents a significant milestone in advancing MBMA's strategy for producing downstream battery materials. This partnership not only highlights the quality of our company, but also reflects the Indonesian government's ongoing support for the domestic minerals and processing industry."

AUSTRALIA

Feasibility study on copper expansion project

BHP has awarded a significant engineering, procurement, and construction management (EPCM) contract to a joint venture between Fluor Australia Pty Ltd and Hatch Pty Ltd. The A$40 million contract is for the first phase of the proposed expansion of BHP's copper smelter and refinery facilities in South Australia, as the company moves towards a final investment decision on the smelter and refinery expansion, currently anticipated in the first half of FY27. The initial stage focuses on strategic planning and development during the project's study phases. Subsequent stages will cover detailed engineering, procurement, and construction management as the project advances.

BHP says that it expects global demand for copper to increase by approximately 70% by 2050 due to the global shift to electric vehicles and renewable energy, and the expanding need for data centres. The company aims to produce more than 500,000 t/a of refined copper cathode by the early 2030s and potentially reach 650,000 t/a by the mid-2030s, a substantial increase from approximately 322,000 t/a in the last financial year. Phase one of the expansion involves a significant upgrade to the existing smelter and refinery at Olympic Dam. This includes a transition to a two-stage smelter and an extension of refinery facilities, ultimately boosting capacity to over 500,000 t/a.

Glencore looking to extend life of Mt Isa

Glencore says it is working with the Queensland government to secure the future of the Mount Isa copper smelter. The company had previously indicated that it would close the smelter in 2030, but recent media reports suggest that the government is looking at assistance to keep the smelter operational, which currently treats more than 1 million t/a of copper concentrate and supplies sulphuric acid to other industries locally, including phosphate production.

CHINA

Attempts to rein in smelter overcapacity

The Chinese government has issued a development plan for the country's copper smelting industry covering the years 2025-27 which is looking to reduce the level of overcapacity in the sector. New copper smelters must now control sufficient copper mine supply via ownership or equity stakes to cover their production requirements, something few smelters do at present. Chinese smelter output has reached record levels, with treatment charges falling to historically low levels as producers compete for copper concentrate – China imports around 85% of its copper concentrate. Meanwhile more smelter capacity is planned, with around 1 million t/a of new capacity scheduled for 2025. The country aims to boost domestic copper mine resources by 5% to 10% in three years to secure raw material supply, according to the government plan. China will also encourage copper smelters to sign long-term purchase agreements with global miners, boost imports of copper blister and anode, and encourage scrap imports.

PHILIPPINES

Nickel Asia sells its stake in Coral Bay

Nickel Asia Corp. (NAC) says that it has completed the sale of its 15.6% stake in Coral Bay Nickel Corp. to its Japanese partner Sumitomo Metal Mining. Nickel Asia says that the sale has been due to "unfavourable market conditions" for the high pressure acid leach (HPAL) nickel processing plant. Although Coral Bay is regarded as one of the most efficient HPAL units in the world, nickel prices have been extremely volatile over the past few years and stood a 4-year lows in January at around 15,000/t, their lowest level since September 2020. Nickel Asia still owns a 10% stake in the Taganito HPAL Nickel Corp.

Glencore's Philippine copper smelter put into maintenance

Philippine Associated Smelting and Refining (PASAR) has put its plant on Leyte Island into care and maintenance to evaluate the operation amid what it termed as increasingly challenging market conditions.

"The asset will be maintained in a state of readiness whilst we continue to monitor market conditions and consider future options and opportunities," the Glencore-managed company said.

The Leyte smelter-refinery produces copper anodes, as well as cathodes used in electricity cables, telecommunication wires, copper shapes and copper-alloy products, as well as by-product sulphuric acid and selenium powder.

GERMANY

Aurubis earnings up 17%

Aurubis AG has reported operating earnings before taxes of euro130 million ($134.8 million) for the first quarter of its fiscal year 2024/25, up around 17% on the figure for the equivalent period of last year (€111 million or $115.1 million). The company's Custom Smelting & Products (CSP) segment posted €125 million ($129.7 million) in EBT compared with €107 million ($111 million) in the previous year. CSP comprises production facilities for processing copper concentrates as well as for manufacturing and marketing standard and specialty products, such as cathodes, wire rod, continuous cast shapes, strip products, sulphuric acid and iron silicate, via smelters in Hamburg and Pirdop, Bulgaria. The company attributes the higher EBT to higher metal prices, considerably increased sulphuric acid revenues, and robust earnings from copper product sales and lower costs, which more than compensated for a year-over-year decline in treatment and refining charges with lower concentrate throughput.

"The robust operating result of the first three months of the current fiscal year is another example of how Aurubis is continuing to build on its success. Our metals are the key to the energy and mobility transition," Aurubis CEO Toralf Haag said. "Our cash flow developed positively despite intense investment in our international smelter network. This endorses our solid business model, successful even in macroeconomically challenging times."

BRAZIL

Yara to suspend acid, phosphate production at Cubatão and Paulínia

Yara says that it plans to wind down production of phosphate fertilizers and sulphuric acid at two sites in Brazil; Cubatão and Paulínia. The sites are expected to cease production by 3Q 2025, as part of what Yara describes as a strategy to concentrate on more sustainable operations focused on its main activity: the production of nitrogen fertilizers. At Cubatão, the suspension will affect unit 3 and the phosphate plants of unit 2, while units 1 and 2, responsible for the production of nitrogen, in addition to the mixer (unit 5), will continue to operate normally. Yara reported a net loss of $290 million in 4Q 2024, down $536 million from the $246 million profit it made in 4Q 2023. Revenues are down 11% for the year, leading Yara to announce a cost reduction and investment program of $150 million, with the aim of optimising its operations and focusing on strategic areas to ensure long-term sustainability. At the same time, the company has begun renewable ammonia production at Cubatão.

SWEDEN

LKAB begins work on phosphate demonstrator plant

LKAB has begun construction of its new demonstration plant for processing phosphorus and rare earth elements at Luleå. The facility is the first in a planned industrial park and, says LKAB, marks an important step in the company's ambition to diversify its business with new minerals. The supply of phosphorus for mineral fertilizers is essential for food security in Sweden and the EU, while rare earth elements are critical for the electrification and digitalisation of society, such as the production of permanent magnets for electric vehicles and wind turbines. The $75 million demonstrator plant is planned to become operational in 2026. The aim is to further develop and verify the process for utilizing material flows from iron ore production in Gällivare, where apatite concentrate is produced for further refinement and production of critical minerals in Luleå. Through a stepwise expansion, the operations can then be scaled up with additional processing facilities over time, aiming for full operation during the 2030s. Once fully operational, the industrial park's production will be approximately seven times Sweden's needs and 6% of the EU's demand for phosphorus in agriculture. Currently, there is no mining of rare earth elements in Europe.

"The world has now turned its attention to metals and minerals once again. We are currently almost entirely dependent on imports for phosphorus and rare earth elements, while demand is rising sharply. By extracting these critical minerals, LKAB can make better use of the material we already mine and strengthen our future competitiveness, while also improving security of supply and preparedness in Europe. This facility is a crucial building block to make that possible," says Jan Moström, President and CEO of LKAB.

SENEGAL

Major phosphate expansion announced

Chemical Industries of Senegal (ICS) has launched two projects to increase phosphate fertilizer production in the country. At a company event, new managing director Mama Sougoufara said that between 2014 and 2023, ICS has expanded production to 2 million t/a of phosphate rock, 600,000 t/a of phosphoric acid, and 250,000 t/a of phosphate fertilizer. The new expansions, with a price tag put at $475 million, include a plant at Mbao to increase fertilizer output from 250,000 t/a to 600,000 t/a, as well as a new phosphate rock processing plant, increasing output by 300,000 t/a. The company has seen its financial situation improve in recent years thanks to its takeover by the Indorama Group, though the Senegalese government retains a 15% stake.

INDIA

PPL signs MoU for phosphate expansion

Paradeep Phosphates Ltd (PPL) says that it has signed a memorandum of understanding with the government of Odisha state to invest $440 million over five years to increase its phosphate fertilizer production and export capacity, including port/jetty and infrastructure development. PPL currently has capacity to produce 400,000 t/a of urea and 2.6 million t/a of finished phosphates, via DAP and NPK plants in Paradeep, Odisha, and Zuarinagar, Goa. Details of the expansion were not announced, but the company previously said in December 2024 that it had agreed to expand phosphoric acid capacity from 500,000 t/a to 700,000 t/a to increase backwards integration of production and reduce dependence on imports.

CHILE

Anglo and Cochilco to combine operations

Anglo American and Codelco have signed a memorandum of understanding (MoU) with the aim of jointly developing their neighbouring Los Bronces and Andina copper mines in central Chile.

"By putting in place a joint mine plan and optimising the use of our respective processing plants, we believe we can unlock an additional 2.7 million tonnes of copper production over a 21-year period from 2030, alongside other operational synergies made possible by coordinating our activities across the site," said Anglo American's CEO Duncan Wanblad. The figure equates to an average of around 128,000 t/a. "Our technical teams have been working together for many years to identify the optimal configuration to unlock the full value of this extraordinary mining district," he added.

Maximo Pacheco, chairman of state-owned Codelco, said: "Codelco and Anglo American have been good neighbours for decades. This relationship has developed through more than ten cooperation agreements between the two companies over half a century."

Under the MoU's terms, they will conduct due diligence with the aim of signing definitive agreements in H_2 2025, subject to securing environmental permits for a joint mine plan and regulatory approvals.

If the proposed combination proceeds, a 50:50 owned operating company will coordinate mine plan execution with the resulting production, value generated, costs and liabilities shared equally between Anglo American and Codelco. They will retain full ownership rights of their assets and continue to operation their concessions separately. Anglo American has signed the MoU through its 50.1%-owned subsidiary Anglo American Sur.

FINLAND

Metso launches sustainable new copper leaching process

Metso has launched its new Cu POX leaching process for the copper extraction industry. The company says that, as ore compositions change due to depletion of deposits and increasing environmental and efficiency demands, this solution not only maximises copper recovery but also reduces environmental impact.

The Cu POX process is a hydrometallurgical method for the treatment of copper sulphide concentrates at lower capacities. The heart of the process is Metso's proprietary OKTOP® autoclave unit, where copper concentrate is oxidised under high pressure and temperature. This results in a copper-bearing pregnant leach solution to be further treated in solvent extraction and electrowinning processes, where copper is recovered as high-purity LME Grade A cathodes.

"Copper sulphide minerals require specialized leaching conditions to achieve high recovery rates. Metso's Cu POX leaching uses high-temperature oxidation to convert sulphide sulphur into sulphate and sulphuric acid, ensuring efficient copper dissolution. This technology offers a high-performance solution with high, up to 99%, copper recovery rates, ensuring maximum extraction of valuable metals from the ore. The process also minimizes environmental impact by reducing emissions and optimising the use of resources through, for example, closed loop process steps reducing the use of water," says Petteri Pesonen, Technology Manager, Copper Hydrometallurgy at Metso.

The scalable Cu POX process accommodates various capacities and raw material compositions. The predesigned process and equipment package enables fast ramp-up to production and integrates seamlessly with solvent extraction and electrowinning (SX/EW) infrastructure. The Cu POX plant can also be implemented to improve existing heap leaching – SX/EW operations to complete depleting heap leaching pregnant leach solution production. In all cases, Metso can provide end-to-end service, from batch tests, modelling and pilot tests to engineering, equipment deliveries and plant commissioning, and training, as well as services, spare parts and digital solutions to optimise continuous process and plant performance.

JORDAN

Foundation stone laid for new acid plant

Jordan's Prime Minister Jaafar Hassan laid the foundation stone for the second phase of Jordan Phosphate Mines (JPMC) new sulphuric and phosphoric acid plants at Al-Shidiya in a ceremony in mid-February. The Phase II expansion aims to increase the sulphuric acid plant's production capacity from 2,200 t/d to 4,450 t/d (1.5 million t/a). The phase will generate an additional 20 MW of energy per hour, with the potential to export 9 MW. The project will also boost the production capacity of the phosphoric acid plant from 900 t/d to 1,600 t/d (equivalent to 550,000 t/a P_2O_5). Construction is expected to be completed, and operations begun by September of this year. With the expansion of the industrial complex in Aqaba and future projects involving potash and partnerships in the phosphoric acid industry, JPMC plans to increase its local consumption to 70%, while reducing external exports by 30%. ■

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 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48

People

Fatema Al Nuaimi.

ADNOC Gas has appointed **Fatema Al Nuaimi** as its new Chief Executive Officer, effective January 1st, 2025. This appointment follows the resignation of Ahmed Alebri, who led the company for nearly two years and has assumed the role of CEO at ADNOC Sour Gas. Al Nuaimi, an accomplished industry leader with extensive experience within ADNOC's gas and energy sectors, is tasked with steering ADNOC Gas' ambitious growth strategy focused on business expansion, decarbonisation, and future-proofing operations.

In a statement, ADNOC Gas said, "In her new role, Al Nuaimi will lead the delivery of ADNOC Gas' ambitious business strategy that is focused on growth, decarbonisation, and future proofing".

Al Nuaimi previously served as executive vice president for Downstream Business Management at ADNOC and brings a wealth of leadership experience to her new position. Prior to that she held the role of CEO at ADNOC LNG from 2019-22, during which she played a key role in advancing the company's strategic initiatives and optimising ADNOC's gas master plan. Al Nuaimi also holds influential positions across ADNOC entities, serving on the boards of ADNOC Offshore and Emirates General Petroleum (Emarat), as well as on the executive steering committee of ADIPEC. She additionally chairs ADNOC's Gender Balance Committee, reinforcing the group's commitment to diversity and inclusion.

ADNOC says that Al Nuaimi's leadership is set to drive operational excellence and support decarbonisation efforts in alignment with the UAE's energy transition goals, and that her appointment marks a significant milestone as ADNOC reinforces its position as a global energy leader, with a focus on innovation, sustainability, and strategic growth.

OCP Africa, the agricultural development subsidiary of Morocco's OCP Group, has announced a key leadership change. During a board meeting on January 27, 2025, the resignation of **Mohamed Anouar Jamali**, who served as CEO for the past four years, was formally accepted. The board expressed its deep appreciation for Jamali's pivotal role in advancing the company's mission to boost agricultural growth across Africa.

Under Jamali's leadership, OCP Africa strengthened its reputation as a catalyst for agricultural transformation on the continent. His tenure saw the company deepen partnerships with farmers, local institutions, and global organizations, propelling innovation and sustainable growth. In recognition of his contributions, the board commended his visionary leadership that helped the company achieve critical milestones.

To ensure continuity, the board has appointed **Mohamed Hettiti** as interim CEO for a three-month period. Hettiti brings a wealth of experience from over 25 years in leadership roles within the OCP Group. He previously served as OCP Africa's operations director and as the first vice-president for East Africa operations, making him well-versed in the company's strategic priorities.

Hettiti's academic achievements include an engineering degree from the prestigious École Mohammedia des Ingénieurs, an Executive MBA from HEC Paris, a second MBA from a joint program between Columbia Business School and HEC, and advanced certifications in transformational leadership from Harvard Business School. His credentials highlight a proven ability to manage complex projects and drive strategic transformation.

In his interim role, Hettiti will be tasked with maintaining OCP Africa's growth momentum while ensuring its initiatives remain aligned with the overarching goals of the OCP Group. The board has expressed full confidence in his ability to lead the organization through this crucial transitional period.

Incitec Pivot has named group financial controller **Damian Buttler** as interim chief financial officer (CFO), as it continues its search to replace former CFO Paul Victor. Buttler brings 20 years of experience in various senior financial roles and is a long-standing member of the IPL team, having been with the company for 15 years. He has extensive experience across business finance and corporate finance roles, working across functions such as treasury, tax, financial planning and analysis, controlling, commercial finance and manufacturing finance. Prior to his appointment as Interim CFO, he held the role of Group Financial Controller and Business Unit CFO. ■

Calendar 2025

APRIL

7-9

World Copper Summit, SANTIAGO, Chile
Contact: CRU Events
Tel: +44 (0) 20 7903 2444
Email: conferences@crugroup.com

8-10

TSI Sulphur World Symposium 2025, FLORENCE, Italy
Contact: The Sulphur Institute, Washington D.C., USA
Tel: +1 202 331 9660
Email: sulphur@sulphurinstitute.org

28 – MAY 2

RefComm Expoconference, GALVESTON, Texas, USA
Contact: CRU Events
Tel: +44 (0) 20 7903 2444
Email: conferences@crugroup.com

JUNE

6-7

48th Annual International Phosphate Fertilizer & Sulfuric Acid Technology Conference, ST. PETERSBURG, Florida, USA
Contact: Michelle Navar, AIChE Central Florida Section
Email: vicechair@aiche-cf.org
Web: www.aiche-cf.org

JULY

2-3

SulGas KL Conference, KUALA LUMPUR, Malaysia
Contact: Conference Communications Office, Three Ten Initiative Technologies LLP
Tel: +91 73308 75310
Email: admin@sulgasconference.com
Web: https://sulgasconference.com

SEPTEMBER

9-12

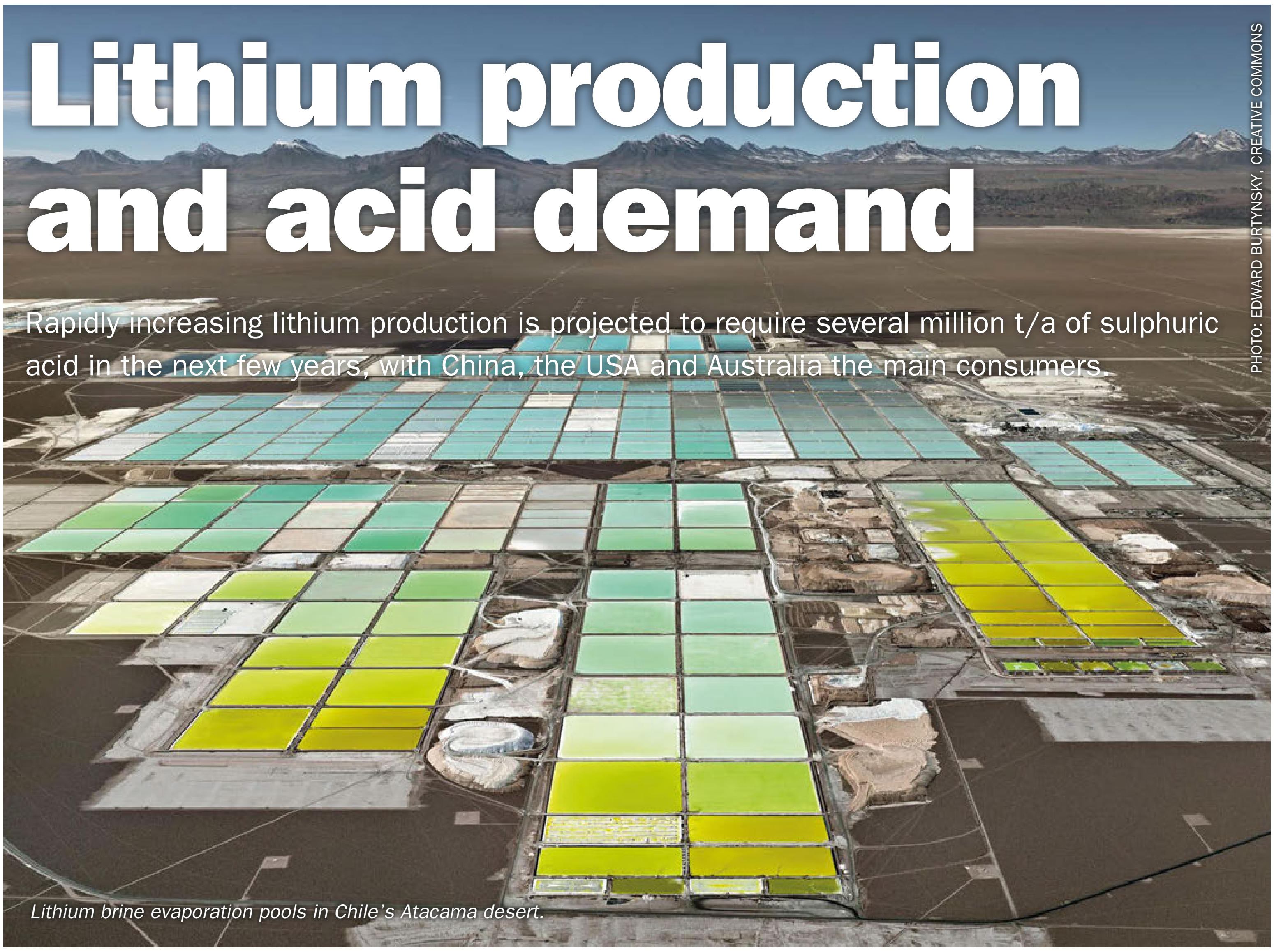
Brimstone Sulphur Symposium, VAIL, Colorado, USA
Contact: The Brimstone Group LP
Email: info@thebrimstonegroup.com
Web: https://www.thebrimstonegroup.com/symposium/

10-11

Oil Sands Expo, CALGARY, Alberta, Canada
Contact: Bruce Carew, EventWorx
Tel: +1 403 971 3227.
Email: marketing@eventworx.ca

Lithium production and acid demand

Rapidly increasing lithium production is projected to require several million t/a of sulphuric acid in the next few years, with China, the USA and Australia the main consumers.



Lithium brine evaporation pools in Chile's Atacama desert.

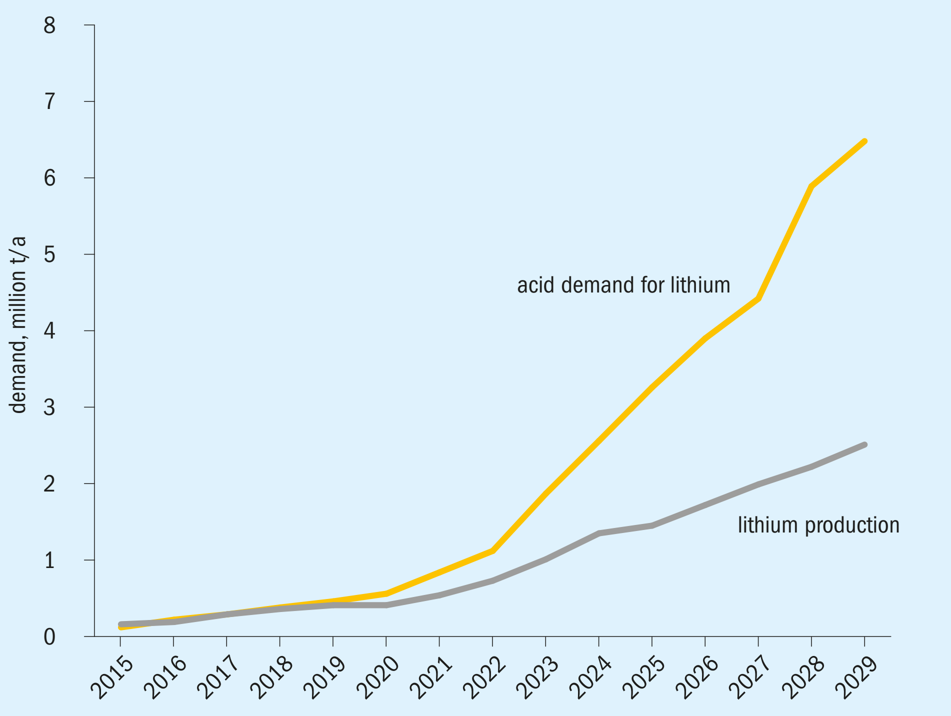
Global demand for lithium is increasing rapidly, driven mainly by its use in various battery technologies. As Figure 1 shows, demand has tripled in the past five years, and is projected to double in the next five.

Lithium production

Lithium deposits are not widely spread globally. Ther US Geological Survey estimates that, of around 30 million tonnes of economically attractive lithium reserves, 9.3 million tonnes are in Chile and 7.0 million tonnes in Australia, 4 million tonnes in Argentina, 3 million tonnes in China and 2.8 million tonnes in the USA. These five countries collectively represent 90% of all deposits.

There are basically three main methods of producing lithium; from brines, either by solar evaporation or a new process called direct lithium extraction (DLE), or conventional hard rock mining of lithium containing ores, mainly spodumene, a lithium aluminium silicate. Rock mining was the dominant

Fig. 1: **Lithium production and acid demand, million t/a**



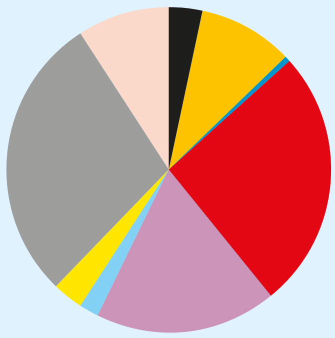
Source: CRU

method of extraction until the 1990s, when recovery from brine deposits became the most widely used source. Surface or underground salt deposits and brine pools are mixed with water and pumped into large evaporation pools to concentrate the lithium, using calcium hydroxide to precipitate out unwanted metals like magnesium and boron, before being processed using soda ash (sodium carbonate) to produce lithium carbonate. However, brine processing is a slow process and very water intensive; a resource not always widely available in the salt flat regions where the processing takes place. As a result, the pendulum has swung back towards rock mining in recent years. Rock mining is followed by conventional mineral processing: crushing, concentration, and roasting and/or leaching using sulphuric acid, to obtain a lithium concentrate. As in brine-based lithium extraction, lime is added for the removal of magnesium (a constituent element in spodumene), and soda ash is used to precipitate lithium carbonate from the final purified, filtered solution. In Nevada, lithium exists in clays which are treated with sulphuric acid to extract the lithium.

Direct lithium extraction (DLE) has been used in China and South America. Brine is extracted from the basin aquifer and pumped to a processing unit where a resin or adsorption material is used to extract lithium, while spent brine is reinjected into the basin aquifers. The resin adsorbs lithium chloride, which is then stripped using water. The lithium solution is then further concentrated via reverse osmosis and mechanical evaporation stages before standard industry processes are used to produce battery-grade lithium.

In 2023, rock mining accounted for 66% of all lithium production, mainly in Australia, solar brine evaporation another 24%, with South America and China the main locations, and DLE about 10%, again in South America and China. Figure 2 shows the main lithium producing nations at present.

Fig. 2: **Lithium production by country, 2025 (estimated), t/a**



Lithium demand

Rapidly increasing demand for mobile or remote electrical power, especially from the vehicle sector, is driving demand for lithium. High power density per unit weight and rechargeability are leading them to replace older battery technologies like alkaline batteries for portable electronics or lead acid cells for vehicles. There are roughly speaking six main lithium battery technologies;

- Lithium iron phosphate (LFP) batteries use phosphate as the cathode material and a graphitic carbon electrode as the anode. LFP batteries have a long life cycle with good thermal stability and electrochemical performance. Low cost means that LFP has been a popular choice in China for EV batteries in spite of lower energy density than some other technologies.
- Lithium cobalt oxide (LCO) batteries have high specific energy but low specific power. This means that they do not perform well in high-load applications, but they can deliver power over a long period. LCO batteries were common in small portable electronics such as mobile phones, tablets, laptops, and cameras. However, they are losing popularity to other types of lithium batteries due to the high cost of cobalt and concerns around safety.
- Lithium manganese oxide (LMO) batteries use lithium manganese oxide as the cathode material. This chemistry creates a three-dimensional structure that improves ion flow, lowers internal resistance, and increases current handling while improving thermal stability and safety.
- Lithium nickel manganese cobalt oxide (NMC) batteries combine the benefits of the three main elements used in the cathode: nickel, manganese, and cobalt. Nickel on its own has high specific energy but is not stable. Manganese is exceptionally stable but has a low specific energy. Combining them yields a stable chemistry with a high specific energy. NMC batteries are used in some electric vehicles.
- Lithium nickel cobalt aluminium oxide (NCA) batteries offer high specific energy with decent specific power and a long lifecycle. This means they can deliver a relatively high amount of current for extended periods. They are also a popular choice for electric vehicles, such as Teslas.
- Lithium titanate (LTO) batteries replace the graphite in the anode with lithium titanate and use LMO or NMC as the cathode chemistry. Wide operating temperature range and long lifespan make them suitable for aerospace applications and stationary power.

LFP has become a popular choice due to cost, particularly in China, and particularly among Chinese smart EV producers, such as NIO, Xiaomi Auto and Li Auto. The world's largest EV manufacturer, BYD, recently announced that they have now equipped more than 2 million new energy vehicles with LFP starter batteries, instead of the incumbent lead-acid – reportedly reducing lead consumption by 20,000 t/a. LFP batteries are lighter, and while initially costlier than lead-acid, may last up to ten times longer – meaning lower costs over the battery lifespan.

Chinese investment in LFP production has led to overcapacity and a fall in lithium prices; in 2024 lithium carbonate prices averaged nearly two-thirds lower than in 2023. However, CRU anticipates that demand will catch up with supply during 2025, in part due to some curtailments in lithium supply in e.g. Australia, with production down 14% on forecasts. LFP cathode production is also at record levels, growing 94% in 2024. Soaring LFP output, powered by strong Chinese EV sales and booming energy storage demand, will be a key driver of the lithium price recovery in 2025 in spite of slower growth in EV purchases outside pf China.

In addition, there has been booming demand from the energy storage sector. Since 2022, battery energy storage systems (BESS) demand has grown sevenfold, far outpacing e-transportation. Much of this growth is being driven by the economics of power storage, new supportive tender mechanisms, longer term contracts, arbitrage and grid stabilisation services – with a third of last years' installations in major markets not directly connected to renewable energy installations. In addition, BESS demand will benefit from solid growth in the solar PV sector, with solar module costs and prices expected to remain low in 2025. BESS usage has also benefitted from LFP over-production, with storage system bid prices falling below the $100/kWh level in China. Although LFP alternatives like sodium-ion will start to proliferate, cost parity is not likely to be achieved until later in the decade. Overall, CRU expects BESS demand to grow more than 70% year on year in 2025 for the third consecutive year.

As shown in Figure 1, the prospects for lithium continue to be bright over the medium term, with some analysts predicting a shortage from 2030 onwards due to lack of investment in new mining capacity.

Recent industry developments

Russian nickel-copper producer Norilsk Nickel (Nornickel) has agreed to send copper concentrate and by-product sulphuric acid to China for processing and, in return, will receive technologies from Chinese partners to enable production of battery materials from Russia's lithium deposits, as part of a new, four-year strategy for moderate growth. Nornickel is working with Russian nuclear power supplier Rosatom on a lithium project in the Murmansk region. The plan is to start construction of an open-pit mine at Kolmozerskoye in 2026 with completion in 2029 and production beginning the following year.

China's Zijin Mining Group has committed to spending $1-3-1.6 billion to construct a 100,000 t/a zinc smelter with capacity for 200,000 t/a of sulphuric acid as a first phase, with a lithium carbonate extraction plant capable of producing 60,000 t/a of battery-grade lithium carbonate to follow in a second phase.

BHP suspended its Nickel West operations from October 2024 until at least February 2027. The decision will remove acid supply from the company's Kalgoorlie nickel smelter, which supplied 550,000 t/a to the regional acid market. While BHP used 250,000 t/ for ammonium sulphate production, external demand is split between 100,000 t/a of lithium-based acid consumption around Kwinana, as well as rare earths and other uses, who will need to import acid from outside the region at increased cost. Nevertheless, the lithium operations remain viable with or without the Kalgoorlie supply. Lithium-based acid demand is forecast to increase from 90,000 t/a in 2023 to over 400,000 t/a by 2028 due to mining expansions. Due to the scale of growth, an increase in imports will be required. Kalgoorlie's closure may therefore necessitate that imports increase sooner.

Table 1: **Projected increase in sulphuric acid demand for lithium production, 2024-29, million t/a**

USA	1.91
China	1.25
Australia	0.39
Indonesia	0.13
South Korea	0.10
Canada	0.06
Germany	0.05
UAE	0.05
Russia	0.04
Brazil	0.03
Total	3.92

Source: CRU

US trade policy

The incoming Trump administration has taken a very different tack on the environment from its predecessor and this may impact upon the EV market. It seems increasingly likely that president Trump will scrap one or both of the 30D and 45X IRA tax credits. The Clean Vehicle Credit (30D) is believed to be at higher risk of repeal compared to the Advanced Manufacturing Production Credit (45X), as the latter attracts significant foreign investment and creates jobs primarily in Republican states. Although Germany's late-2023 removal of consumer subsidies prompted a significant decline in BEV sales, a similar US move is unlikely to be as impactful under the IRA's current guise, because Foreign Entity of Concern rules around critical minerals are so stringent that barely any EVs will qualify from January 2025.

The Trump administration may also consider relaxing emissions standards, which could incentivise OEMs to shift back towards more profitable internal combustion models. Rollbacks of European emissions standards, or the US' CAFE and EPA rules would be a major blow, although probably over longer timescales given that OEMs operate across multi-year development cycles.

Meanwhile, the escalating Sino-American trade war has seen the US place tariffs on a range of Chinese materials – while China is reportedly considering tightening export controls on various battery-related technologies. The US relies on Chinese LFP battery imports to support its booming energy storage system market. BESS operators have very limited alternatives, at least for the next few years. The US also lacks domestic cathode and graphite anode production, relying on imports from China and South Korea. Higher tariffs will inflate battery and EV costs, ultimately burdening consumers. Around 20% of US EV sales are imported from the EU and Mexico, making up over half of total EV imports, and despite growth in the domestic battery sector, supported by IRA 45X subsidies, 31% of US consumption still relies on imports, mainly from China. It seems likely that the current trade war may damage the uptake of EVs in the US, though at present the market is being led by growth in China.

Lithium production expansions

As Table 1 indicates, the main expansions in lithium capacity and concomitant acid demand over the next four years are likely to be in the US, China and Australia. The start of the Lithium Americas and Ioneer projects in the United States will add 1.4 million t/a of acid consumption from 2028 and 1.9 million t/a in 2029. While the US projects are relatively high cost lithium producers and have depended on Department of Energy funding for getting off the ground, Trump's freeze on DoE funding is unlikely to affect projects which have already agreed funding.

Additional Chinese production will represent another 1.25 million t/a of acid demand, and Australia another 400,000 t/a, at a variety of sites mainly across Western Australia, where there has been a focus on cost reduction of lithium production. A number of African projects are expected towards the end of the forecast period but construction has yet to begin and no supply is likely before 2030.

Overall, lithium production is likely to be consuming an extra 4 million t/a of acid by 2029, but as battery use continues to grow into the 2030s, this figure is likely to continue to increase rapidly in the early years of the next decade.

Sulphur in agriculture

Sulphur's key role as a plant nutrient means that its use as a fertilizer continues to be a major area of demand.

Sulphur is a vital nutrient for plant and animal health, and is essential for plants to form proteins, enzymes, vitamins and chlorophyll. Crops with high sulphur requirements include legumes such as alfalfa and soybeans, as well as canola and rapeseed, but because of its effect on nitrogen uptake, it is also important for crops with high nitrogen requirements such as maize and cotton. Persistent experiments show that sulphur application can increase crop yields by around 20%. Sulphur also helps the uptake of other micronutrients, such as zinc.

Sulphur requirements in soils have tended to increase as environmental sources of sulphur have declined, in particular – in industrialised countries – sulphur dioxide emissions from power plants and vehicle exhausts. In the thirty years from 1985-2015, for example, atmospheric deposition of sulphur on fields in the US Mid-West fell by around 80% due to improvements in air quality. This period also coincided with a move away from traditional fertilizers like ammonium sulphate, potassium sulphate and single superphosphate, which had 'coincidentally' contained sulphur to higher analysis fertilizers such as urea, potassium chloride and diammonium phosphate.

The requirement for additional quantities of sulphur fertilizer have been recognised and this is leading to increasing use of sulphur containing fertilizers.


PHOTO: MARSULEX

Ammonium sulphate production from power plant stack gas scrubbing

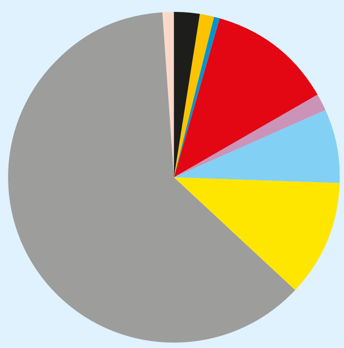
Sulphur vs sulphate

There are essentially two forms in which sulphur can be applied to soils; as elemental sulphur, or as a sulphate. Sulphate is the form in which plants are able to take in the nutrient, as it is soluble and can be transported via water into the roots. Conversely, elemental sulphur must first be broken down by thiobacteria into soluble sulphates before it can become available to the plant, comparable to the way that urea must be oxidized to a nitrate before plants can use the nitrogen, but the conversion process for sulphur is much slower and can take months. This process can be sped up by increasing the surface area of elemental sulphur by using it in a micronised form, or by breaking up sulphur granules into smaller particles. A common technique is to use 5% bentonite clay in the sulphur granule. The clay absorbs water and swells, leading the brittle sulphur granule to fracture. Some of the major developments in the past decade in sulphur fertilization have involved greater control over sulphur particle size and dispersion in conventional fertilizers, leading to a growing range of 'sulphur enhanced' fertilizers.

Sulphur fertilizers

The three main 'traditional' sulphur-containing fertilizer – ammonium sulphate, single superphosphate and potassium sulphate – still represent a significant majority (ca 70%) of sulphur fertilizer applications.

Fig. 1: **AS production by region, 2023**



0.8	Africa
0.5	East Asia
0.2	Europe
3.9	FSU
0.5	Middle East
2.3	North America
3.6	Oceania
19.8	South America
0.3	South Asia

Source: IFA

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 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48

Ammonium sulphate

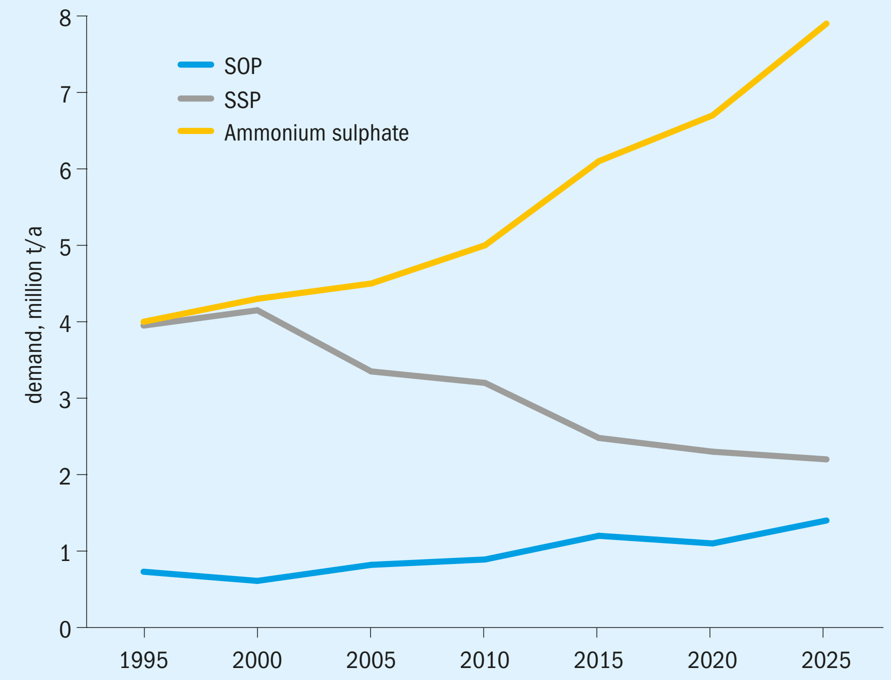
Ammonium sulphate is still the largest sulphur fertilizer by volume. Global ammonium sulphate production was 31.9 million t/a in 2023, or around 7.6 million t/a of sulphur. Figure 1 shows the geographical distribution of capacity. As can be seen, most is in China, where there is a great deal of involuntary production as a by-product of caprolactam manufacture for nylon fibres, methylmethacrylate, acrylonitrile, methionine production etc. Overall around half of all ammonium sulphate production comes as a by-product of caprolactam production, but that figure is higher in China, where the rapid increase in artificial fibre production has led to a major increase in caprolactam production there, and concomitant demand for sulphuric acid. Other major involuntary sources of AS production are ammonia scrubbing of coke oven gas, and as a by-product of lithium iron phosphate production, the latter again increasingly important in China due to the rapidly expanding battery manufacturing industry for electric vehicles. About 70% of AS capacity is based on by-products from other production, and in China this figure is 83%. It is also 90% in Europe and 73% in North America. However, in the Middle East, Africa and South America, the opposite is true, and on-purpose production predominates, between 75% of production (in South America) to 95% (in the Middle East).

Overall, the world consumed around 18.2 million t/a of sulphuric acid in 2024 to make ammonium sulphate, or about 6% of all acid demand. China represented almost exactly half of that acid demand (9.1 million t/a). Chinese AS production has tripled in the past 15 years, and is forecast to grow by another 25% out to the end of the decade as industrial sources continue to grow.

AS consumption is virtually all (95%) as a fertilizer, with its sulphur content becoming increasingly relevant. Consumption is more widely distributed than production, with the strongest demand in Asia (though not China, which uses relatively small quantities) and Latin America – particularly Brazil. There are some exports from Europe, but low operating rates for caprolactam production there means that there are also imports, but the AS trade is dominated by China, which is by far the largest exporter, at 17.1 million t/a in 2024, an increase of 25% on 2023. Chinese exports go mainly to southeast Asia (about 30% of exports) – especially Indonesia, Vietnam and Myanmar – and Brazil, which took 36% of Chinese exports (6.1 million t/a) in 2024. An increasing amount (7% of exports in 2024) go to African countries, especially Nigeria, South Africa and Egypt. The US is also a major importer (1.0 million t/a), but takes AS from Europe, Canada and Mexico as well as China.

Sulphuric acid use for AS production is expected to grow from 18.2 million t/a to 22.7 million t/a in 2029, with China representing around 75% of that, but increased production is expected in western Europe as production there recovers, and some additional production in the US, India and elsewhere. As AS production remains largely involuntary, output tends not to be determined by fertilizer prices but rather the markets for fibres and the other products that it is a by-product of, meaning that AS will probably continue to represent the largest slice of sulphur fertilizer production going forward.

Fig. 2: **Use of traditional sulphur containing fertilizers, million tonnes S per year**



Sources: IFA, CRU

Single superphosphate

Single superphosphate (SSP) is the simplest phosphate fertilizer, made by treating phosphate rock with sulphuric acid. Production is based mainly in Brazil (26% in 2024), India (24%), China (13%) and Australia and New Zealand (12% between them). Egypt is also a major producer. Total sulphuric acid use for SSP production in 2024 was 9.1 million t/a. Because of its relatively low phosphate nutrient content compared to mono- and diammonium phosphate (MAP/DAP), 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 capacity and production fell from 2015 to 2020, as Figure 2 shows, but since then has remained relatively constant, and is even expected to increase slightly towards the end of the decade, with increasing production in India and Brazil masking a continuing fall in Chinese production. Overall SSP production is expected tog row by 7.7% between 2024 and 2029.

Potassium sulphate

Potassium sulphate/sulphate of potash (SoP) has always been a niche product compared to the much more widely used potassium chloride (aka 'muriate of potash'/MoP), but it is valued as a chloride-free source of potash for cash crops such as tobacco, tree nuts and citrus fruits. Global production was 7.8 million t/a in 2024, representing about 1.4 million tonnes S. China accounts for 65% of world capacity, and Germany another 11%. Other major producers are the US, Egypt and Belgium. China also dominates consumption, using virtually all that it mines

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 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48


PHOTO: SHIV SULPHURIC SOLUTIONS

Sulphuric acid plant at Coromandel's Visakhapatnam facility.

in various NPK formulations, but export restrictions are tight, and it exports only a fraction of its production. Both Chinese consumption and production increased by 17% in 2024. North America and Europe are also major consumers. Higher price premiums for SoP in recent years again due to its sulphur content (17-18%) may encourage new production, but long lead times mean that overall production is likely to be flat out to the end of the decade.

Sulphur-enhanced fertilizers

While these three still make up the mainstay of sulphur fertilizer applications, there are an increasing number of sulphur enhanced fertilizers which typically use innovative technologies to incorporate elemental sulphur into higher 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 N and P 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. The market for sulphur-enhanced NP+S products has developed over the past decade, with particular take-up in the US, Brazil, India and parts of Africa.

Controlled release fertilizers (CRFs) can be produced by coating highly soluble nutrients such as urea with relatively insoluble coatings. While India uses the plant fibre neem, other polymers can be used, and elemental sulphur (usually with a polymer outer coating) is also used as a coating – the sulphur breaks down slowly, eventually allowing the encapsulated to become available over a longer time period. India's Rashtriya Chemicals and Fertilizers Ltd (RCF) has introduced a sulphur coated urea which it markets as 'Urea gold', with 37% N and 17% sulphur. The sulphur acts as a controlled release coating for the urea, increasing its nutrient use efficiency, while also providing plant nutrient sulphur. RCF says that it can be applied at 75% of the amount of conventional urea to achieve the same effect. However, at present uptake remains low. At the end of 2024, RCF said that it had sold 12,200 tonnes of Urea gold during the year.

Coromandel International has also recently started up a new 25,000 t/a plant making sulphur bentonite at its Visakhapatnam facility in Andhra Pradesh. Visakhapatnam produces approximately 1.2 million t/a of of complex fertilizers along with phosphoric acid and sulphuric acid. The site also has an sulphur fertilizer plant with 25,000 t/a production capacity, meaning that the new plant will effectively double the site's sulphur fertilizer capacity. Coromandel says that the new plant uses German technology to fortify sulphur fertilizers with multiple micronutrients, addressing evolving nutrient deficiencies in Indian soil.

The popularity of liquid fertilizers in North America, especially liquid ammonia and urea ammonium nitrate solution (UAN) has led to the use of soluble thiosulphates to produce sulphur enhanced liquid fertilizers.

Still room for growth

While reliable statistics are hard to come by, total fertilizer sulphur nutrient consumption is currently estimated to be about 13.5 million tonnes S, against a potential global requirement of 27 million tonnes S. The shortfall is lowest in North America (ca 20%), with Europe and Latin America at around 35%, but for Asia the figure is closer to 50% and in sub-Saharan Africa it is over 90%. Despite growing sulphur nutrient demand over the near term, the gap between supply and demand is projected to narrow. CRU expects the premiums now achievable with sulphur containing fertilizers and the demonstrable success of sulphur enhanced fertilizers to continue to incentivise investment in sulphur-enhanced fertilizer technology to meet projected future demand.

Developments in phosphate markets

Tight supply limits availability as China maintains export restrictions.

The global phosphate fertilizer market has been experiencing persistent supply constraints, mainly due to export restrictions from China. This has kept prices at historically high levels despite affordability concerns and weakened demand in certain key markets. Looking ahead, demand is expected to recover in some regions, particularly India, while other markets, such as Brazil, continue to struggle due to economic factors.

Supply constraints

Phosphate markets have been tight going into 2025. The main reason for this is China. Although China remains the largest global phosphate producer, it has been enforcing strict export controls since 2021. As expected, China brought its restrictions on exports back in December and has continued them through January and February. They are expected to be loosened somewhat in April, following the seasonal pattern that has become established over the past few years, with exports during Q2 and Q3, followed by restrictions in Q4 and Q1. But no fresh export sales from China are expected through Q1 under the current regulatory regime, as authorities seek to push domestic prices down to an acceptable level, with only previously-agreed volumes likely to move. In 2024, total Chinese exports of DAP, MAP and TSP were 7.3 million t/a, and the figure is likely to be the same for 2025. These restrictions have effectively reduced Chinese finished phosphate exports overall by about 35% compared to the 2021 figure. There has been an increase in exports of phosphoric acid rather than finished phosphates, which appears to be an attempt to circumvent restrictions while maintaining some presence in global markets. However, there is significant risk that exports are cut even further in the medium term depending on government restrictions. It is unlikely that restrictions will reverse course, and for exports to increase.

The restrictions are balanced somewhat by expanding supply elsewhere. In Morocco, 2024 was OCP's strongest ever export year, with full year DAP+MAP+TSP exports expected to reach 9.6 million t/a. This year looks to repeat the record, as prices stay high, inputs relatively low and demand looks to recover. OCP has been focusing on ramping up TSP exports, particularly to India, despite setbacks on NBS rates and farmer adoption of TSP. OCP is also expanding exports to Ethiopia. Prospects for Moroccan exports to the US remain limited, however, due to the imposition of duties on Moroccan phosphate imports. This has had a marked impact on OCP's consumption of sulphur and sulphuric acid, reaching 29 million t/a of acid equivalent in 2024, up 32% on 2023. Exports from Morocco may be higher than currently expected, particularly in the early months of 2025. OCP already significantly increased its production and sales, with granular phosphate exports reaching a new record in 2024. OCP likely has tonnes to sell; but it is expected to be cautious in its approach to the market to maintain price support.

In the US, production continues to slide lower. Publicly reported sales of phosphate fertilizers in the United States hit a decade low in 2024 Q3 with total reported sales from Mosaic, Nutrien and Itafos dropping below 2.2 million tonnes, a fall of 9% year on year, as phosphate rock resources are depleted, limiting finished fertilizer output. This, together with duties on Moroccan and Russian imports, are leading to an increasingly tight phosphate market in the US.

Demand constraints

High prices have also had an impact on demand, particularly in the major consuming nations of Brazil and India. In Brazil this has been exacerbated by the depreciation of the real against the US dollar. The ratio of crop prices to phosphate prices is at its lowest level since 2022, and almost since the record low of 2008, limiting affordability. Brazilian demand did not rise in 2024, though there has been a rise in cheaper superphosphate imports, both TSP and SSP, and an expanded planting area for soybean crops. This trend is expected to continue in 2025, with TSP and SSP replacing more expensive MAP and DAP. Some of the demand concerns will alleviated by increased production from the new plant at Serra do Salitre, which commissioned in 2024 and which is ramping up operations. The site has a capacity of up to 1 million t/a, though this is mostly as SSP, as MAP has poorer margins, and the rock is not suited to TSP production. The overall result is expected to be a stagnant or slightly improved demand. Demand for MAP to Brazil has remained slow, with prices stable for seven months at a short-term ceiling around $635/t c.fr. Seasonal buying patterns and worsening affordability have hit the market, and buyers have focused purchasing on cheaper alternatives such as SSP, TSP and NPs, enabling them to maintain overall P_2O_5 stocks at a relatively healthy level despite MAP drawdown, which contrasts to the situation in India. Tight supply should limit MAP price downside, though poor affordability and demand destruction will add downwards pressure.

India has a very quickly growing population and rising agricultural demand as a result. Despite the recent slump in imports and production, this is not expected to persist and CRU projects demand to recover strongly throughout the remainder of the 2020s. According to CRU estimates, India has 900,000 tonnes of DAP in stocks, the lowest level seen since January 2022. Though the first three months of the year are the lowest demand season for India, demand quickly

A reclaimer at OCP's Sidi Chennane phosphate mine, Morocco.

picks up by May as farmers prepare for the Kharif crop. When stocks previously were this low, this was followed by an extremely strong import season the following year. However, that would rely on a significantly strengthened subsidy package for the Kharif (April) season, as importers are facing very poor margins. India's delivered DAP prices have remained stable for more than three months despite seasonal demand slowing. The price had climbed 26% between the end of May and the start of October but has fallen only 1.5% since then. Stocks in India are exceptionally low, supporting off-season restocking demand. Suppliers are aware of this and are resisting any pressure for price cuts. Still, buyers will be sensitive to prices, as import margins remain heavily negative at current prices and under current subsidies.

US phosphate prices remain among the highest in the world due to tariffs imposed on imports from Morocco, Russia, and China, while as noted above, domestic phosphate production has been declining due to poor-quality phosphate rock and weather-related disruptions in Florida. The potential imposition of tariffs on Mexican phosphate exports could further reduce supply, pushing prices even higher.

New capacity

The global phosphate market saw prices peak in Q4 2024, with a combination of weak demand and limited supply leading to stagnation. Although prices are not expected to rise significantly, they will remain at elevated levels due to continued supply tightness. In the longer term, however, new capacity is expected to bring prices down. OCP and Ma'aden are responsible for almost all of the upcoming capacity build out globally. In Morocco, expansion of TSP production is underway, with plans to bring online 1 million t/a of capacity in Jorf Lasfar and an additional 4 million t/a in a new phosphate hub in Safi, in 2027-28. Ma'aden's massive Phosphate III project will bring online 3 million t/a of DAP and MAP capacity in two phases. The first phase is expected in 2027-28, and the second phase around 2030.

Elsewhere, JIFCO has signed a MoU with the Jordanian Chamber of Industry to encourage the company to provide phosphoric acid for domestic fertilizer producers. India's Ostwal group, parent company of MBAPL, has said they expect their new 1.0 million t/a capacity DAP/NPK plant to be commissioned by October 2026. In Egypt, China-based Asia-Potash has announced plants to invest $1.6 billion in Egypt. The project will be an industrial complex to mine 2 million t/a of phosphate and convert them into fertilizers.

High prices to persist

Trade policies, currency fluctuations, and affordability challenges pose risks to market stability. US tariffs on Canadian potash imports have already pushed up prices in that market. If Canada were to impose similar tariffs on US phosphates, that would similarly raise prices there. Rising sulphur prices are also having an impact on phosphates.

While the long-term outlook suggests some relief as new capacity comes online post-2027, the phosphate market will remain tight in the near-to-medium term, making affordability a key concern for global importers. Overall, scarce supply is likely to continue to support prices for granular phosphates despite poor affordability relative to downstream agricultural products as well as other nutrients, though there is potential for further price downside from Q2 2025.

Sulgas Mumbai 2025

Building on the success of its previous conferences, SulGas Mumbai 2025 brought together 154 sulphur and gas treating stakeholders, representing 68 companies for its 7th technical forum in the Indian subcontinent. We report on some of the key topics on the agenda.

The 7th SulGas® Conference, organised by Three Ten Initiative Technologies LLP, took place from 5-7 February 2025, at the Holiday Inn, Mumbai.

The conference featured 25 speakers in interactive technical sessions, fostering maximum technical exchanges among participants. Alongside the conference a dedicated exhibition area provided full-day access for all delegates. The conference agenda featured ten sessions. Each session concluded with a detailed panel discussion, sparking valuable dialogue between the audience and speakers.

The key themes of the conference were:

- **Foundations masterclass** – foundation training in the fundamentals of process instrumentation for sulphur recovery units, presented by Anatha Kukkuvada of Ametek Process Instruments.
- **Gas processing and troubleshooting** – providing field insights into process reliability, best practices for SO_2 breakthroughs, case studies on iron sulphide contamination in gas treating and issues of a liquid treater.
- **From biofeeds to beyond Claus** – including decarbonisation, biogas catalyst, and green refining guidelines.
- **SRU process automation and instrumentation** – case studies providing field insights, technology advancement, optimisation with AI and gas analysis using process analytics.
- **Gas processing: Challenges and innovations** – simulation of trace component handling, solvent technology for selective treating and technology advancement in automation.
- **Integrated approach to SRU optimisation** – real time monitoring for decarbonisation, field insights on preventative maintenance and technology advancement in simulation.
- **Minimising risks in SRU start-up and shutdown** – operations and analyser best practices for safe transitions.

Some of the topics discussed at the conference are highlighted below.

Amine absorber fouling

A frequent problem in Indian refineries is amine absorber fouling. When this happens, the amine and gas supply must be temporarily stopped so the vessel can be cleaned. Usually there is not enough time to thoroughly clean the tower and the equipment remains partially fouled, shortening the interval before cleaning will be needed again. This problem is costly and time consuming. Ben Spooner of SGS Amine Experts described how to predict when the risk of absorber fouling increases and how to prevent, or at least delay, the adverse effects. By using a combination of good amine analysis, appropriate operation methods and an understanding of the equipment design, engineers and operators can take control of the amine plant.

SO_2 breakthrough in the SRU TGT

The tail gas from the Claus section of a sulphur recovery unit (SRU) contains small amounts of unconverted H_2S, SO_2, COS and CS_2 and traces of sulphur as mist or vapour. In a typical tail gas treating (TGT) unit based on the reduction-absorption-regeneration process, the TGT design includes a quench column downstream of the hydrogenation reactor, mainly to cool the reactor effluent gases before it enters the amine solvent in the absorber column. The quench column also serves as a guard against possible SO_2 slippage from the upstream hydrogenation reactor into the amine solution, which has the potential to result in major plant upsets and be the cause of permanent damages and losses in the SRU.

Typically, the first response to tackle SO_2 breakthrough is to address the "symptom", the drop in pH in the quench water circuit. Neutralising agents (ammonia or caustic) are injected or dosed to bring the pH back to normal values, but in many cases, due to the delayed action from the operator, there can be significant damage to the downstream amine system. Fluor provides a design which provides sufficient time for the operator to prevent SO_2 reaching the downstream amine system. However, this does not address the real cause and does not provide a "cure" to this condition. Debopam Chaudhuri of Fluor explained how continuous monitoring of key operating parameters has the potential to reduce and even eliminate the chance of any SO_2 breakthrough, thus providing longer run lengths and longer operating lives for the SRU.

Closing the cycle by spent acid regeneration

In downstream operations, H_2S is generated in processes where sulphur-containing hydrocarbons are treated to remove sulphur and meet stringent environmental standards for fuel emissions. Typically, H_2S is first converted to sulphur in a sulphur recovery unit, then transported to an acid plant to produce sulphuric acid, requiring two separate facilities. Paul Zorn of P&P Industries explained how P&P's Sulphur Oxidation Process (SOP) provides a more efficient alternative by converting H_2S directly into sulphuric acid in a single plant. This eliminates the need for sulphur production, transport, storage and operation of two plants. The SOP technology is established and has been successfully implemented in operational plants, including those incorporating spent acid treatment. High acid concentration (>98.5%) or oleum production can be achieved with add-on units.

COS and mercaptans removal

Gas and liquid hydrocarbon streams from refineries and gas plants must be well cleaned of sulphur compounds such as H_2S, COS and mercaptans, dictated mainly by environmental constraints. Although a copper

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PHOTO: SULGAS

SulGas® 2025 provided the opportunity for experts to engage with their peers and discuss advanced technologies and best operating practices with technology providers, vendors, and licensors.

strip test may indicated acceptable sulphur content today, COS slowly reverts to H_2S and CO_2 in the presence of water so the same test administered tomorrow may fail. Users of legacy simulators have complained for years that predicted COS removal has been far removed from observations. That deviancy has now been rectified, Jeff Weinfeld of Optimized Gas Treating introduced a new model for COS absorption into alkaline solvents based on mass transfer rates enhanced by reaction kinetics, the first time that commercial software has had the ability to simulate this aspect of COS absorption accurately.

SRU Energy and cost optimisation

Most operating companies consider the SRU as a license to operate and therefore, if the SRU is working reliably and the emission targets are met, little attention is paid to optimise the unit. However, with modern monitoring algorithms, historical data availability and active support of the unit engineer and technology specialist, both financial as well as sustainability improvement can be achieved.

Together with Slovnaft, Worley Comprimo has developed a near real-time monitoring system dashboard using data sharing via the Cloud. Proprietary KPIs have been developed and tested for their relevance. Using a two-year data set containing minute average data, trends and insights were used to optimise performance. Claudia Guarino of Worley Comprimo described the main learnings and improvements with respect to energy optimisation which supports sustainability targets for Slovnaft.

Tubesheet protection system inspections

Tubesheet protection systems (ceramic ferrules) are one of the most vulnerable refractory systems in a sulphur plant. Failure analysis is a very complicated systematic process, requiring extensive knowledge and experience in order to reach the proper conclusions. Ceramic ferrule and tubesheet lining problems are often the first symptom of a problem, regardless of origin (plant design, installation, operation and/or maintenance). One broken ferrule, undetected, can cascade into an unplanned shutdown, equipment damage, premature corrosion of tube welds and metallurgy and eventual leaks. Domenic Misale of Industrial Ceramics presented a blueprint that has proven to be a useful tool for methodical visual tubesheet production system inspection.

Continuous BTEX emission monitoring from SRU furnace

Dr Abhijeet Raj of IIT Delhi discussed how by using a previously created precise reaction mechanism for Claus furnace simulations, a simplified reaction model for the degradation of aromatics in the furnace was constructed to create a BTEX soft sensor. The generated kinetic model was incorporated into the Aspen HYSYS software to perform Claus furnace simulations. For a sufficiently broad range of acid gas flow rates, air flow rates, fuel gas flow rates and the concentrations of H_2S, CO_2 and BTEX in the acid gas feed, the model was able to predict the furnace temperature withing a 5% error margin and the BTEX concentration within a 5 pm error margin based on comparison with plant data. The great accuracy of the plant data predictions made by the BTEX sort sensor suggests that it can be used in SRUs to continuously measure the amount of BTEX that leaves the reaction furnace.

Mid-IR tunable laser analysers for SRU applications

Tunable laser gas analysers have been successfully proven in many demanding process control applications. Dr Pawel Lluczynski of Airoptic reported on the successful installation and operation of a tunable laser based air demand analyser for an SRU process. It was put into operation at one of Sweden's refineries, where it has been operating continuously in a closed loop for process control since 2023. The laser air demand analyser offers several advantages over UV analysers such as: high sensitivity, excellent selectivity, facilitates real-time data acquisition, suitable for varying conditions and non-destructive measurements. In addition the laser analyser does not require extensive sample conditioning, simplifying deployment and reducing maintenance needs.

Pioneering practices in green refining

In a green refinery, the concentration of acid gas from the amine regeneration unit has an extremely low H_2S content, which originates entirely from the addition of dimethyl sulphide (DMDS) as there is no sulphur in the feed to the HDO unit. Separating and recycling the H_2S reduces the need for continuous DMDS addition, helping both the environment and economic efficiency by decreasing chemical consumption. Ayan Dasgupta of Fluor introduced an innovative system that eliminates the need for an SRU by employing a two-unit approach that combines a conventional amine recovery unit with a specialised unit unique to green refineries, termed the H_2S Enrichment Unit (H2SEU). The H2SEU unit effectively increases the H_2S concentration from the very low levels in the feed gas to the required to allow it to be recycled back into the process. ■

Registrations are now open for SulGas®'s first sulphur recovery and gas treating conference in Kuala Lumpur, 2-3 July at Impiana KLCC.

PHOTO: SULGAS

All smiles at the Worley Comprimo stand.

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 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48

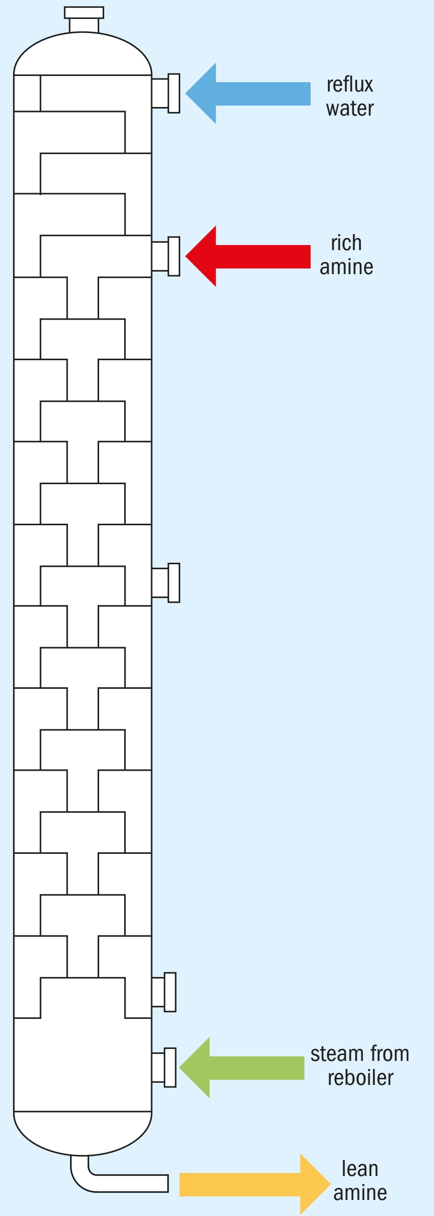
Preventing regenerator amine carryover

Amine is meant to enter near the top of a regenerator and only flow steadily downwards. Several factors exist that can reverse this direction and cause the amine to flow upwards instead, running the risk of entering the sulphur recovery unit. This can have catastrophic consequences and must be avoided at all costs. **B. Spooner** and **M. Sheilan** of SGS Amine Experts detail how by correctly interpreting operating data, having proper instrumentation and good chemical analysis, amine carryover can be prevented.

Amine systems are continuous circulating loops, where the amine goes from being loaded up with acid gases to being unloaded. The amine regenerator (also referred to as a still, stripper or reactivator) is designed to do the unloading; it removes H_2S and/or CO_2 from rich amine, enabling amine to be reused. The acid gases driven from the amine then flow from the regenerator to the downstream processing unit, which is often a sulphur recovery unit (SRU) if there is enough H_2S present to warrant one. In low H_2S systems, alternative destinations for acid gas can be compressors (for re-injection into the ground), thermal oxidisers or sometimes the gas is simply vented. No matter the destination, amine carryover with the gas is always detrimental and should be completely avoided. Regenerators are typically designed with protection against amine entrainment with the acid gas, but sometimes accidents happen – accidents that can be avoided with proper operation and troubleshooting abilities.

A typical amine regenerator is shown in Fig. 1. Reflux water enters onto the top tray. The rich amine stream enters on usually the 2nd or 3rd tray from the top, but in some locations, there can be as many as four reflux trays. There is a vapour return line from the reboiler entering in the lower part of the column, and the regenerated (lean) amine exits from the bottom. There are many variations to these designs; variations that may affect amine carryover will be discussed in this article.

Fig. 1: **Generic amine regenerator**



Source: Amine Experts

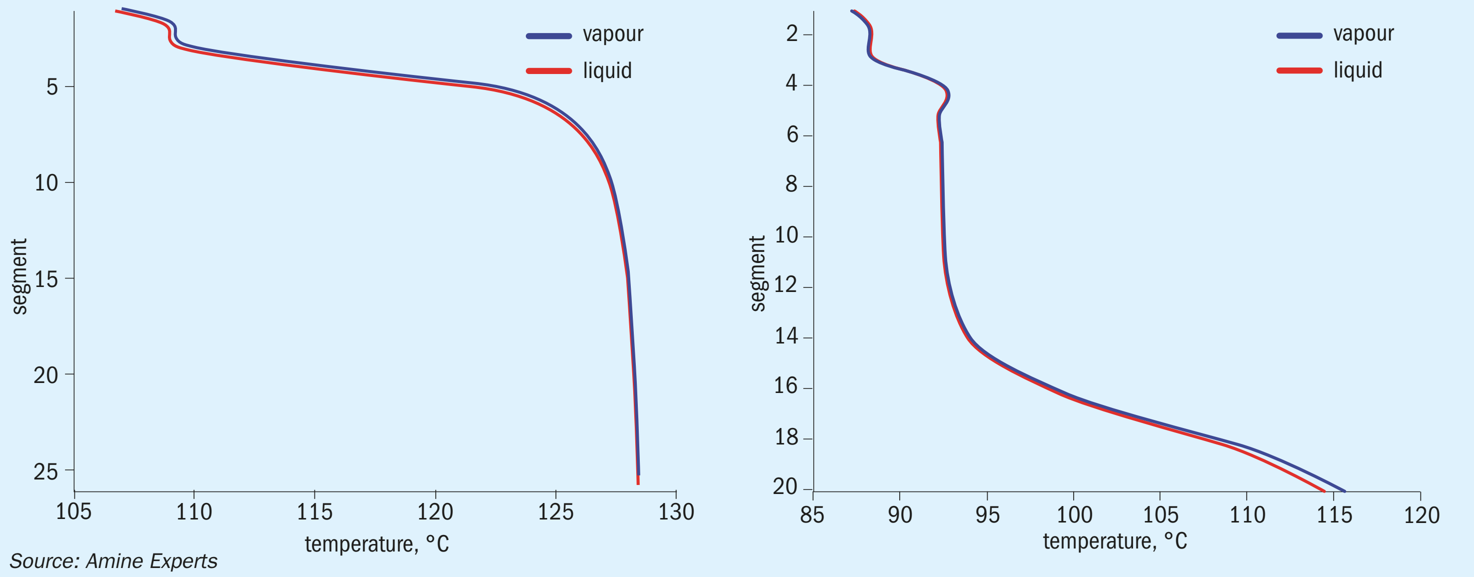
Regeneration fundamentals

Proper understanding of how regenerators operate helps considerably with preventing amine carryover. The following aspects will be used through this report.

When amine enters the regenerator, it should immediately contact steam and be heated. The increase in amine temperature inside the regenerator is referred to as sensible heat (the energy required to raise the temperature of a substance; measurable with a thermometer). The amount of sensible heat required is a function of the amine flow rate and temperature; the lower the flow and higher the regenerator feed temperature, the less sensible heat duty is required inside the tower. Most of the sensible heating should be done in the first few trays (or one metre of packing), after which point the amine should be only a few degrees from its boiling point.

If the reboiler does not produce enough steam, and there is inadequate sensible heat available when the rich amine enters the tower, the amine simply does not heat up. It flows down the regenerator at the same temperature it entered until closer to the bottom where it then encounters the small amount of steam from the reboiler. Because amine does not regenerate until it is heated, this "collapsed temperature profile" means most of the acid gases and, potentially, foam-promoting contaminants will be pulled to the bottom of the tower. Acid gases liberated from the amine will enter the vapour space and

Fig. 2: **Regenerator temperature profiles - proper (left), and improper (right)**



Source: Amine Experts

attack bare, non-amine wetted metal (the most common areas of attack are just below the bottom tray or packing support, or in the vapour space of a kettle-type reboiler and steam-return line).

Examples of both proper and improper regenerator temperature profiles are shown in Fig. 2:

Operators can determine the correct amount of heat medium to the reboiler using a combination of parameters:

Heat medium-to-amine ratio: The required ratio varies from plant to plant, but good starting points for fresh amine systems are listed in Table 1. A variety of units is displayed.

Table 1: **Heat medium-to-amine ratios**

	kg steam/m³ amine	lb steam/gal amine	MJ/m³	MBTU/gallon
MEA	115	1	247	0.0088
DGA	115	1	247	0.0088
DEA	108	0.9	230	0.0082
MDEA	102	0.85	219	0.0078
MDEA + Piperazine*	108	0.9	230	0.0082

Source: Amine Experts

**The concentration of piperazine and rich CO_2 loading heavily influences required reboiler heat duty*

Overhead temperature: In conjunction with the pressure of the regenerator overhead, the temperature determines the water content, which in turn determines the "stripping ratio", or the ratio of water to acid gas leaving the stripper tower (in moles). Most amines require a stripping ratio of at least 1, and some up to 4. This generally equates to a regenerator overhead temperature of 100ºC or higher although, like with any aspect of amine plant operation, there are plenty of exceptions. The desired stripping ratio for the amine should be used to determine the target overhead temperature. In general, the recommended minimum stripping ratio for each amine is:

- MEA: 4
- DGA: 3
- DEA: 1.8
- MDEA: 0.9 - 1.3 (very plant-specific)
- MDEA + piperazine: 0.9 – 1.5 (depending on piperazine concentration)

Ineos GAS/SPEC® has developed a handy cheat sheet which provides good estimates for determining the correct overhead temperature at various regenerator pressures, shown in Fig. 3.

Ratio of reflux-to-amine flow: An "old school" approach to amine regeneration is to increase heat duty to the reboiler until a certain flow of reflux water is achieved. This was done in the days before a glance at a DCS screen could tell the operator the regenerator overhead temperature. Most of the older amine plants were MEA, where the rule of thumb was for the reflux flow to equal 10% of the amine flow. Different amines have different required reflux-to-amine flow ratios:

- MEA: 10%
- DGA: 7%
- DEA: 5%
- MDEA: 3-4%
- MDEA + piperazine: 3-5%

Lean loading: This is the least important parameter of setting regenerator conditions. If the first three parameters (heat medium setpoint, overhead temperature, reflux flow) are all correct, the amine will be well enough regenerated that the risk of corrosion is mitigated. The problem with lean loading is that the value is largely affected not only by reboiler duty but also by the heat stable amine salt (HSAS) concentration. The strong HSAS acids drive out the weaker H_2S and CO_2, so amines with even a small amount (0.5 wt-% or greater) of heat stable salts will, by default, have a very low lean loading. Lean loading measurements are not necessarily useful for setting operating parameters but can indicate problems in the system. For example, a higher-than-expected lean loading can mean the amine is contaminated with a strong base (usually sodium) or there is channelling in the regenerator.

Reasons for amine carryover

Amine can carry-over into the reflux system, and potentially with the acid gas, for several reasons:

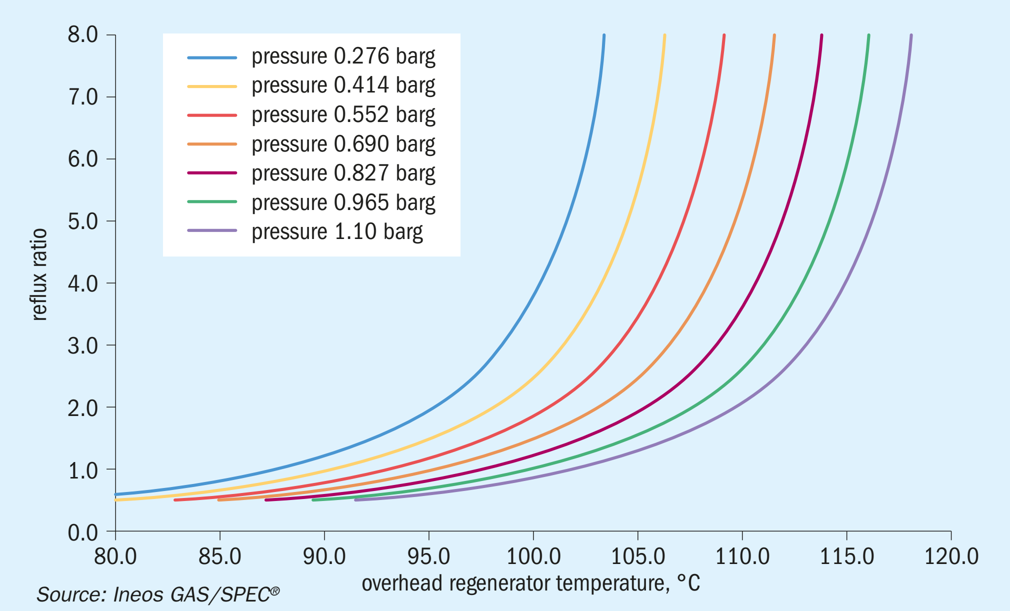
- **Foaming**: When amine is in a foam state, the foam travels upwards, growing in height until it carries over the top of the tower.
- **Flooding**: If more amine is pumped into the regenerator than can flow down, it will flow up instead. Fouling of the tower internals dramatically increases the likelihood of this scenario.
- **Entrainment**: An excess amount of upward vapour traffic can lift amine up and out the top of the tower.
- **Design deficiencies**: Towers designed without reflux trays, or where there is only a small disengaging space between where the rich amine enters and the steam leaves are much more prone to amine carry-over. Towers where the trays are too close together also run higher risks of amine entrainment.
- **Operations**: Not understanding symptoms of the above problems will allow for a small problem to become a big problem. Carry-over generally does not happen immediately and without warning; proper understanding of the chemistry of amine and reflux water along with education regarding the values on the DCS screen will prevent all but the most extreme examples of unexpected upsets.

Foaming

The most common reason for amine loss from a regenerator is foaming. Foaming is when the bubbles formed in the amine do not 'pop'. The foam builds on top of the amine level either on the trays or on top of a section of packing until it flows out of the top of the tower with the steam. Amine and reflux samples should be regularly foam tested by bubbling gas through a bubbling device located at the bottom of an amine sample. The foam height should be measured, as well as the length of time it takes for the foam to disappear after the bubbling stops. These two parameters are referred to as foaming tendency and foaming stability. The amine foam test apparatus used by Amine Experts is shown in Fig. 4.

Trayed columns are far more at risk of foaming compared to those that are packed. Nonetheless, both styles of regenerator can foam. The main symptoms of regenerator foaming are:

Fig. 3: **Reflux ratios at various regenerator overhead temperatures and pressures**



Source: Ineos GAS/SPEC®

- increasing differential pressure;
- loss of bottoms liquid level (or reboiler level depending on the design);
- increasing liquid level in the overhead accumulator.

The order in which these symptoms occur can be used to determine where in the tower the foaming originated and, therefore, how to troubleshoot it before it results in excessive carryover.

Foaming originates in the bottom: If the first symptom is a loss of bottoms or reboiler level, followed by an increase in dP, and finally an increase in overhead accumulator level, this indicates the foaming originated on the bottom tray, or possibly within the reboiler itself. Because the amine is being converted to foam and is now travelling upwards, it is starving the bottoms section of liquid. Either the liquid level will drop, or in the case of regenerators with level control valves on the lean amine outlet, the level control valve will start to close. The lower section of a regenerator is the hottest area of the amine plant, so for a foam-promoting contaminant to reach this area it is either very stable (non-volatile) or the overall temperature of the regenerator column is too low to have vaporised the contaminant higher up in the tower.

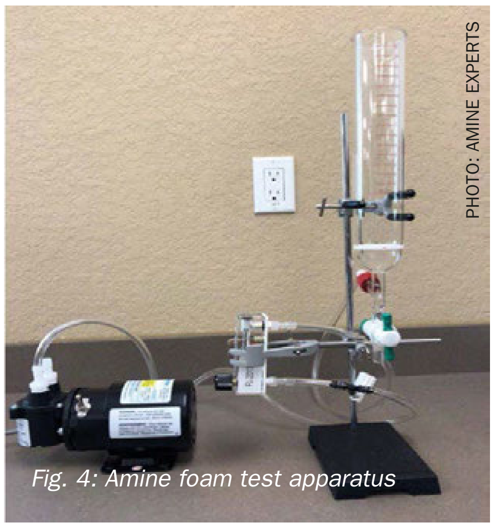


Fig. 4: Amine foam test apparatus

Foaming originates in the middle: If the initial symptom is an increase in dP, but with no change to bottoms level or amine carryover for a minute or two, the foaming started in the middle of the column. Often this is from operating with a partially collapsed temperature profile, where the contaminant is allowed into the bottom section of the regenerator. The contaminant may vaporise in the hot bottom section but then condense in the cooler upper section. This "yoyo" effect causes a bubble of contaminant to build inside the tower, eventually leading to foaming. This can be eliminated by increasing the reboiler heat duty, sending more steam up through the regenerator and repairing the collapsed temperature profile.

Foaming originates in the top: If the only symptom is amine carryover, with little or no change in dP, and a delayed effect on bottoms level, this indicates the foaming started very high up in the tower. This is the most dangerous type of foaming, as there is little warning to the operator. Either the amine was contaminated and ready to foam the moment it was agitated upon entry to the regenerator, or it blended with contaminated reflux water, and the combined amine/reflux blend then foamed.

Foaming troubleshooting

Before developing a foaming-mitigation plan, foam tests should be performed on the reflux water as well as the lean and rich amine. The temperature profile of the regenerator should also be known, which is best done by using a simulation program.

Foam test results:

- **Rich amine**: This sample should be taken after the flash tank (if the system has one), before the lean/rich exchanger. If the sample's foaming tendency or stability is high, the flash tank may require optimisation. Flash tanks are designed to remove gas and liquid phase hydrocarbons, which are often foam-promotors. Gas-phase hydrocarbons will flash off if the tank pressure is low enough. The flash tank pressure should be only high enough to "push" the gas to its destination and the rich amine into the regenerator (assuming the system does not have rich amine pumps). The amount of pressure needed to push rich amine to the regenerator can be determined by the flash tank level control valve opening; it should be 60-70% open. If it is less than this, the tank pressure can be lowered, which will increase the hydrocarbon removal efficiency.

  Rich amine can also be contaminated by suspended solids, which also exacerbate foaming by increasing the foam stability. Rich amine filters can go a long way to reducing foaming problems in regenerators by removing these particles. In the lab, foam test the rich amine then filter the sample and re-do the foam test to note if there is any improvement.
- **Lean amine**: Lean amine should be sampled after the lean/rich exchanger and before the activated carbon bed. If the sample exhibits high foaming tendency, this indicates the foam-promoting contaminant has gotten through the regenerator/reboiler. This can normally be solved by increasing the steam flow through the regenerator, raising the temperature of the column. If not, the activated carbon should be used to remove the contaminant, which is likely non-volatile and may be a heavy hydrocarbon.
- **Reflux water**: If the sample is foamy, this is a good sign as it means the regenerator is working to drive contaminants out of the amine. The operator should then purge as much reflux water as possible, ideally until the samples show low foaming tendency. If the sample is not foamy, however, yet the lean amine is and/or there are symptoms of foaming in the regenerator then the steam flow through the tower should be increased for several hours, then the reflux water re-sampled. If the foaming tendency increases after raising the steam flow, it means the regenerator is now vaporising the contaminant, and the reflux should then be purged.

If the reboiler duty is already more than adequate, and the regenerator temperature profile is correct, it means the foam promotor is not volatile. Injection of a tested, proven antifoam will collapse the foam back to liquid, carrying the contaminant with the lean amine. An activated carbon bed can then be used to remove the contaminant.

In summary, if the foaming is suspected to be originating in the bottom or middle of the regenerator, increase the ratio of heat medium (steam, hot oil, glycol, etc) to the reboiler in relation to the amine flow. The contaminant will hopefully be vaporised higher up in the tower and not cause foaming.

If the foaming is originating in the very top of the regenerator, improve the operation of the flash tank, and investigate if installing rich amine filters will help.

Once the contaminants have been vaporised, they tend to concentrate in the reflux water, which should be purged.

Until the amine is free of foam-promoting contaminants, antifoam should be injected, either into the rich amine or the reflux water, to prevent amine carryover. Antifoam mobilises the contaminant into the lean amine, where it should be removed by activated carbon.

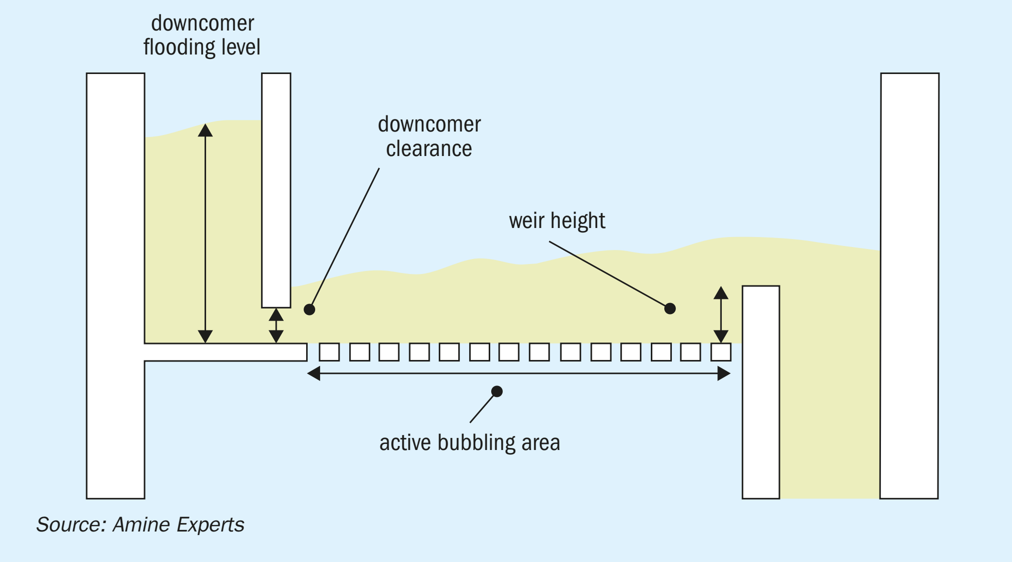
Flooding

Knowing the hydraulic limitations of the regenerator is important to prevent flooding of the tower. Trayed towers are more prone to flooding than packed, because the amine level in the downcomer can build up if the circulation is too high. The height of the liquid in the downcomer should not exceed 85% of the downcomer's volume. All commercial simulators will predict the downcomer flooding if accurate tray information is entered into the program, including the tray diameter, active area, weir height and downcomer clearance (shown in Fig. 5). If this information is not known, then the current flows should be compared to the design flows; as long as the flows do not exceed 120% of the design, there should not be flooding as most towers are designed to have 70% downcomer flood.

Flooding can also occur, even if flows are within the hydraulic limits, if there is fouling in the tower. Trays can foul inside the downcomers, eventually blocking the flow through the downcomer clearance. Packing is more likely to foul than trays, so rich amine cleanliness is therefore more important when packing is used. Fouling is normally detected by gamma scanning. The symptoms of flooding are similar to fouling, with a few key exceptions:

- adding (a tested, proven) antifoam does not stop the carryover or lower the dP;
- the carryover is continuous regardless of steam flow through the tower.

Fig. 5: **Trayed regenerator details**



Source: Amine Experts

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 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48

Unfortunately, there is no good quick fix for fouling. The unit should be shut down and cleaned.

Entrainment

If the steam flow is excessive, amine will be physically carried over by the high vapour flow. Similar to troubleshooting possible flooding, the design value of the steam flow should be known, or at least the design heat medium flow to the reboiler. The steam flow in the tower (or heat medium flow to the reboiler) should be within 120% of design. Alternatively, use an amine simulator to perform the calculations. The vapour flow through the tower is measured by "jet flood". At jet flood levels of above 85%, droplets of amine will start to be carried upwards with the steam, and entrainment losses become possible. Amine losses by entrainment manifest as a steady, consistent but low level of amine carried into the reflux system. The reflux water will therefore contain higher-than-normal levels of amine which can be measured by a digital refractometer and inferred by pH measurements.

In trayed towers, the tray spacing can affect the chances of entrainment. Trays are typically spaced 610 mm apart, however in some cases the spacing is lower, for example 450 mm. The closer the trays are together, the higher the risk of entrainment since the amine does not have to carry the amine up as high before it will be lifted to the tray above. The type of tray also plays a role; sieve trays allow the steam to flow straight up compared to most valve trays where the steam enters each tray horizontally. Towers with sieve trays are, therefore, especially prone to entrainment. The plant engineer should be aware of the tower internals, which can heavily influence the risk of entrainment.

Entrainment does not normally result in high enough volumes of loss that the amine would get all the way to the SRU, but it may be a contributor if other carryover mechanisms are also occurring. Because foaming is a combination of contamination and agitation, if the jet flood is so high that entrainment is occurring, it also means the amine is being highly agitated and foaming is much more likely even if the level of contamination is somewhat low.

Design deficiencies

The design of the tower certainly plays a role in determining the risk of amine carryover. Some design parameters that should be paid attention to when troubleshooting amine carryover are:

- Trays too close together (610 mm spacing preferred, 450 mm minimum).
- Tray type (sieve trays are more prone to entrainment due to high vertical vapour velocity compared to valve trays, where the gas is forced to enter the trays horizontally).
- Packing size too small.
  - The amine and steam are forced through smaller areas, increasing vapour velocity.
  - Smaller packing fouls easier than larger.
  - 38 to 50 mm (1.5 to 2") packing size is normally appropriate.
- No reflux trays
  - Some tower designs do not include reflux trays. Instead, the reflux is returned to the system either to the flash drum or it combines with the rich amine and the two liquids enter the tower together. There are pros and cons to all designs, but certainly reflux trays will generally act as "water wash" trays and minimise amine carryover from entrainment or vaporisation. If the reflux water is contaminated, however, it will promote foaming in the top of the regenerator and make carryover worse. Reflux trays, in general, will reduce amine carryover with steam, but the reflux water must be clean so as not to promote foaming.Simulations can be used to estimate the amount of amine in reflux water; for example, in a regenerator operating with overhead conditions of 104°C and 83 kPag (220°F, 12 psig) Table 2 lists the expected amine carryover with the steam.
- No reflux water purge
  - Reflux water often contains foam-promoting contaminants and should have a mechanism to purge all or part of the flow so that these contaminants can be removed from the system. Without a purge, the contaminants will be pumped back into the amine, which can cause foaming and amine carryover.

Operations

Operators must understand the values on the DCS screen of the amine regenerator and recognise when carryover potential exists. Many large carryover problems can be stopped before they start by diligent board operators. At a minimum, these values must be monitored, especially if the numbers are changing:

- **Reflux accumulator level**: If this level is rising, it almost certainly means amine carryover is occurring. Ideally this would have been prevented by monitoring other parameters listed below. At this point immediate action must be taken such as antifoam addition or even cutting heat medium to the reboiler, or further carryover to the SRU is very possible.
  - In Amine Experts' experience, if the acid gas line fills with amine, much of it will be caught in the acid gas knock-out (KO) drum just upstream of the SRU. Although this protects the SRU, liquid flowing through the acid gas line will carry a lot of debris into the KO drum. It can even block the vessel drain. If the KO drum level remains high even with the drain valve open, check it right away for blockage, or the drum will fill and spill directly into the reaction furnace!
- **Overhead temperature**: The two main causes of large-volume amine carryover are foaming and flooding. Both will impact the overhead temperature but in different ways. Flooding tends to condense more steam since there's a large volume of liquid the steam is fighting through. The overhead temperature will, therefore, decrease. On

Table 2: **Expected amine carryover using 0 to 3 reflux trays**

No. of reflux trays	MDEA in overhead stream kmol/h	MDEA in reflux water wt-% (46°C/115°F)
3	$3.2e^{-14}$	$1.4e^{-14}$
2	$5.5e^{-10}$	$2.4e^{-9}$
1	$1.3e^{-4}$	$5.7e^{-4}$
0	0.168	0.7

Source: Amine Experts

the other hand, if the regenerator is suffering from foaming, the steam will not be condensed as efficiently since there is not significant heat transfer between steam and foam. In this case the overhead temperature will increase. Sudden changes in the overhead temperature, either up or down, should be flagged and investigated immediately.

- **Differential pressure**: Depending on what and where the problem is, an increase in differential pressure (dP) may be the earliest warning sign of amine carryover. If the dP is rising but there are no other changes (no amine carryover, no loss of bottoms level), likely the foam or flooding is starting in the middle/bottom of the column and climbing upwards.
  - Antifoam should be added to either the rich amine or the reflux streams; observe if the dP lowers back down. If so, foaming was to blame, and it was caught before it resulted in carryover. To prevent this from recurring, increase the steam flow through the tower and vaporise the foam-promoting contaminant so it does not reach the lower section of the tower where steam flow and, therefore, agitation of the amine is higher.
    - The reflux should then be purged, since the vaporised contaminants will build up in the water.
  - If antifoam has no effect, heat medium to the reboiler may need to be reduced. This should be as temporary and to as small of a degree as possible, since a lack of steam flow will allow acid gases into the reboiler which is very corrosive. But it is better than carrying amine over towards the SRU. However, this is a short-term fix and the root cause of the high dP must still be determined. A gamma scan may be necessary if fouling is suspected.
- **Bottoms liquid level**: A loss of bottoms level can indicate amine is being "hung up" in the tower, starving the bottom of the regenerator. To make sure amine is being continuously fed to the reboiler, check the flash tank level control valve is not 100% open – if it is, increase the flash tank pressure and investigate if possibly the rich amine filters or lean/rich exchanger are plugged.

  If amine is flowing into the column but not moving downwards, inject antifoam immediately, before there is a level increase in the reflux accumulator.

  If a loss of bottoms level is the first indication of problems, it means the amine is making its way most of the way down the tower before running into difficulty (any other scenario and the dP or amine carryover would happen first). This usually means there is not enough steam traffic in the tower and contaminants are able to flow too far downward. Increase steam flow to prevent the situation from recurring.
- **Lean/rich amine and reflux water foam tests**: Operations has a vested interest in the foaming tendency of the amine and reflux water samples. If the lean or rich amine, or reflux water foaming tendency is increasing, it often means problems are building in the regenerator. In plants struggling with amine carryover from the regenerator, foam testing of these three samples should be performed regularly. ■

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How to successfully run a four-year acid plant campaign

Apart from having a good plant design, good maintenance practices and good operational discipline are key to optimise the performance of an acid plant and to protect it from corrosion and achieve a long life. **B. Mumba**, **T. Mwanza** and **P. Ng'ambi** of Kansanshi Mining PLC explore the Kansanshi sulphuric acid plant operations and the key parameters monitored and practices adopted that have helped to extend the catalyst campaigns from two years to four years.

Kansanshi copper smelter was commissioned in March 2015. The off gas from the primary smelting furnace, Isasmelt™ furnace, and off gases from the Pierce Smith converters are treated in a single 4,500 t/d acid plant. The successful operation of the acid plant has been very important to the successful operation of the smelter and has allowed the smelter to treat concentrates at a rate of more than 110% of the design capacity. Details of the Kansanshi smelter operations and acid plant design and operations are described in other publications[1,2].

In the early years of the smelter operation, the acid plant ran for very short campaigns before stopping the plant to screen the catalyst, the shortest one was only 10 months. The decision to stop the plant was driven by high pressure drops across the catalyst beds, particularly Bed 1 and also the opportunity to screen during the smelter turnaround.

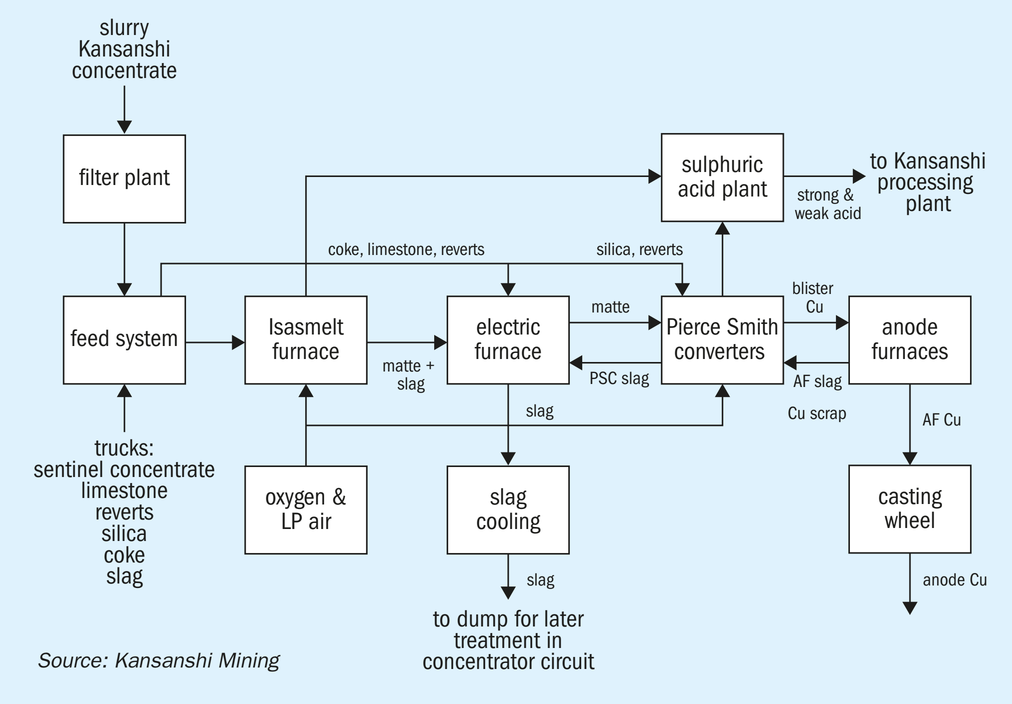
The original schedule for acid plant and smelter turnarounds were two years and four years respectively. The acid plant turnaround is centred around catalyst screening which takes between two weeks to one month to finish depending on the number of beds to be screened and the performance of the screening machines. The smelter shutdowns are usually scheduled for about 40 days which is enough time to screen all the beds. Therefore, any catalyst screening conducted outside of the scheduled times has a big impact on the smelter availability. It is therefore beneficial to reduce the frequency of catalyst screening by screening only during the smelter turnarounds.

This article explains some of the operations and maintenance strategies that have been adopted and adapted at Kansanshi smelter that have helped to increase the acid plant turnaround time from two years to four years while still maintaining low pressure drops on the SO_2 converter beds and maintaining concentrate treatment above the rated plant capacity.

Brief process description

Fig. 1 below shows the general process flow of the Kansanshi Smelter. Copper concentrates are smelted in an Isasmelt furnace which produces a matte of between 58% and 60% Cu. The off gas from the furnace goes through a waste heat boiler and spray coolers where it is cooled to between 330°C and 350°C. The gas is passed through a dry electrostatic precipitator (ESP) where the majority of the dust carry over is captured and

Fig. 1: **Kansanshi smelter process flow**



Source: Kansanshi Mining

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 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48

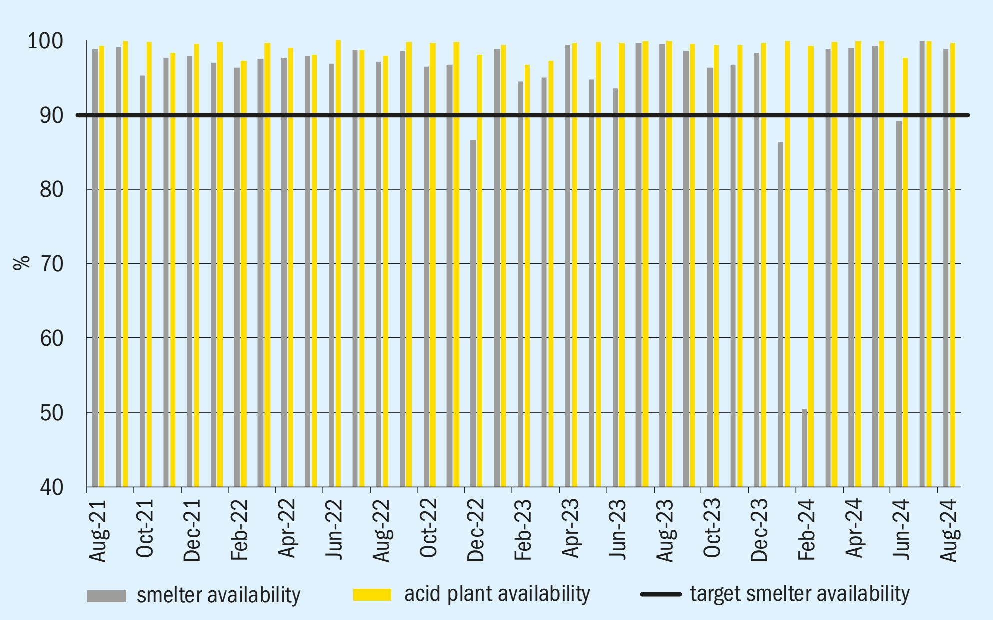
removed before it is taken into the gas cleaning plant.

The matte from the Isasmelt is converted to blister copper in Pierce-Smith converters (PSCs). Each PSC is coupled with a standalone primary gas cooling and cleaning system which consist of an evaporative cooling chamber (ECC), a high efficiency scrubber, a droplet separator and an intermediate blower.

The gases from the Isasmelt route and the PSCs meet in a common duct before they go for final cooling in two parallel packed gas cooling towers (PGCTs) and final gas cleaning in four parallel wet electrostatic precipitator (WESPs) trains, each consist of one primary WESP and one secondary WESP.

The final gas is taken to the acid plant for conversion and absorption processes.

Fig. 2: **Acid plant and smelter availability**



Source: Kansanshi Mining

Smelter and acid plant performance

Plant availability

The acid plant operations are an integral part of the smelter operations hence the smelter availability is highly dependent on the acid plant availability. Fig. 2 shows the overall smelter availability and the acid plant availability on a monthly basis between August 2021 and August 2024. It can be seen from the graph that the acid plant availability was consistently above the plant design of 90%. During this period, there has been no requirement to screen the catalyst which has contributed to higher than design availability for acid plant. The overall smelter availability was also above 90% for most of the months during the period except for three months in which there were unplanned failures on the oxygen plant and Isasmelt.

Catalyst screening history

Table 1 shows the history of the catalyst screening. During nine years of operation of Kansanshi Smelter, the catalyst in Bed 1 has been screened a total of five times while the rest of the beds have been screened twice only. The catalyst has been screened both on scheduled shutdowns during smelter turnarounds and on emergency stoppages because

Table 1: **Kansanshi Copper Smelter Acid Plant SO_2 converter catalyst screening**

Campaign No.	Time of stoppage	Campaign duration, months	Reason for stoppage	Beds screened	Changes implemented	Achievement
1	Aug 2016	17	Unplanned stoppage – Isasmelt refractory failure	Bed 1 top layer		Bed 1 ΔP reduced from 2.5 kPa to 1.5 kPa
2	Jun 2017	10	Planned stoppage – smelter turnaround and acid plant turnaround	Beds 1-4	Pressure instrument installed to measure pressure drop across the top layer only. Introduced sodium silicate dosing on the packed gas cooling towers in 2018.	Bed 1 ΔP reduced from 2.2k Pa to 2.0k Pa
3	Aug 2019	26	Planned stoppage – Acid Plant turnaround	Bed 1		Pressure drop reduced from 4.7 kPa to 1.2 kPa
4	Jun 2020	10	Unplanned stoppage – High P in Bed 1	Bed 1	Introduced two new catalyst types on top of Bed 1 which included 25mm dust trapping catalyst	Bed 1 ΔP reduced to 1.0 kPa from 5.0 kPa
5	Jun 2021	12	Planned stoppage – smelter turnaround and acid plant turnaround	Beds 1-4		Bed 1 ΔP was maintained below 2.0 kPa for more than 3 years of continuous operation

Source: Kansanshi Mining

of high pressure drop across the catalyst beds, especially Bed 1. The catalyst screening can only be done during the dry season because the converter is located outside of any enclosed building and all the manholes are exposed to the outside weather.

The first catalyst screening was carried out in 2016 during an unplanned stoppage of the smelter. Only the top half of Bed 1 was screened. At that time the pressure drop across the bed had already reached 2.5 kPa from 1.3 kPa after only one year of operation.

The following catalyst screening was during a planned smelter turnaround in 2017. All the four beds were screened; it was observed that in bed 1 the catalyst was deteriorating quickly. A Layer of catalyst dust was found in the middle of the top layer resulting in high pressure drop. Fig. 3 shows the Bed 1 pressure drop from 2015 to September 2024 together with catalyst screening shutdowns.

After 2017 smelter turnaround shutdown target for smelter campaigns was increased from two years to four years. However, with only one year of operations, Bed 1 pressure had increased rapidly, to more than 5 kPa hence a catalyst screening shutdown was required for Bed 1 only in 2019. The root cause of the more rapid catalyst deterioration in Bed 1 was unknown. An additional pressure transmitter was installed in the middle of the bed to assist with troubleshooting. It was found that pressure drop in the top of the catalyst bed was increasing more rapidly than the bottom half.

The suspected cause of the catalyst degradation was fluorine which at that time was not analysed in concentrates or in the acid. When the feed concentrates were analysed and it was found that the concentration of fluorine was much more than the concentrations used for the design of the plant. To address the problem, sodium silicate dosing was introduced in July 2018 on the packed gas cooling tower to scrub off the fluorine in the gas before it reached the catalyst. The smelter lab was equipped with a fluoride analyser to measure once per shift the fluorine levels in both the strong acid and weak acids as well as a daily assay of fluorine in the feed concentrates.

Even after the sodium silicate dosing was implemented, the problem of rapid increase in the pressure drop across Bed 1 did not go away, but rather worsened as the dust continued to form in the bed. After 2019 catalyst screening shutdown, another shutdown for screening Bed 1 catalyst was necessary in 2020 only 10 months after the previous screening. This was driven by rapid increase of pressure drop across Bed 1 together with significantly increased pressure drop across the hot heat exchanger.

In the 2020 shutdown, half of the top layer of bed 1 was changed to a new type of catalyst and the hot heat exchanger was cleaned. The scale sample taken from the hot heat exchanger indicated that it had been blocked by catalyst dust. The change of the catalyst type eventually stopped the rapid deterioration of catalyst and an improvement in the performance of the catalytic converter was observed. In 2021 all the converter beds were screened again during the scheduled smelter turnaround shutdown and the remaining portion of the Bed 1 top layer was changed to the new type of catalyst and a dust capturing layer was introduced on top of Bed 1.

The converter was entered in January 2024 during an unplanned smelter stoppage to check the condition of the catalyst after 2.5 years of continuous operation and the catalyst sampled in a few places and it was found to be in good condition without any pockets of dust.

Strategies for managing and improving acid plant campaign

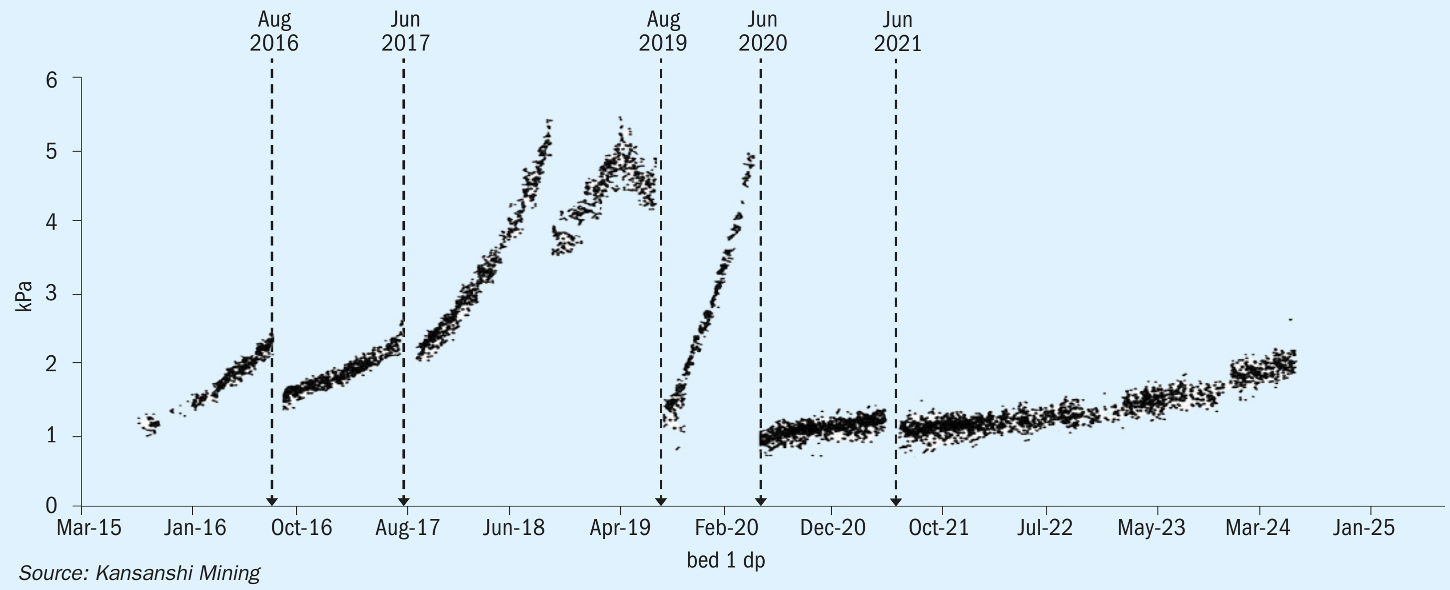
Gas cleaning plant operations

The operations and efficiency of the gas cleaning plant (GCP) has a large bearing on both availability of the acid plant and the length of campaign the catalyst can achieve[3]. The GCP removes dangerous poisons such as dust, halides, mercury, excess moisture etc. that would affect both the acid absorption system and catalytic converter if not removed from the gas. Attention must be paid to all operations in the GCP to minimise plant downtime and enhance efficiency. Below are some of the strategies that have been adopted and adapted at Kansanshi in the gas cleaning section.

Maintaining high pressure drop on the high efficiency scrubber's dampers

The high efficiency scrubbers (HES) require a high pressure drop across the damper on

Fig. 3: **Bed 1 pressure drop and catalyst screening**



Source: Kansanshi Mining

the scrubber throat for the dust in the gas stream to be caught by the water droplets in the circulating slurry. Each of the HES units is equipped with a movable damper. To maintain a high differential pressure, the damper position is continuously adjusted by a differential pressure controller; the damper is partially closed when the gas flow is low and opened more when the gas flow is high. There are two sets of transmitters to measure the pressure drop on each unit, this is for redundancy in case of bad readings from one instrument the control room operator switches over to the second one. On the PSCs gas route, the HES have several sets of setpoints for the different operating modes of the converters i.e. one set of parameters for slag blow mode and another for copper blow mode.

Maintaining high liquid to gas ratio in scrubbers and PGCTs

The scrubbers and the packed gas cooling towers are supplied with excess liquid. Each of the units has two independent circulation circuits to supply the quenching and the cooling liquids respectively. Each circuit supplies enough liquid to sufficiently cool the incoming off gas for a limited period, about 30 minutes. The oversupply of liquid ensures that no hot gas goes past the HES and protects the FRP ducting downstream.

Maintain high weak acid bleed-off

High volumes of make-up water added to GCP so that the bleed-off of solids from the system is very high. This intervention has not solved the problems of solids accumulating in the circulation pipes but has reduced it to a small extent. The high make-up water dilutes the acid concentration in the system from maximum of 10% to 11% to only about 1% H_2SO_4. This reduces the corrosiveness of the acid to the equipment and bolts[4].

Data recording and trending

The analysis of trends plays an important role in the operations of the smelter. The data collected from the DCS and manual log sheets are recorded in a process historian (PI system). Trends are monitored both by the control room and any plant personnel with access to a computer. Some trends have been developed specifically to assist the control room operator to more quickly check different sections of the plant. Daily monitoring of the trends has helped to ensure that all the units are running efficiently and deviations in the process can be worked on in a timely manner. Planned maintenance is also scheduled based on equipment performance assessed from the data from trends.

Manual cleaning of WESP tubes

The dust particles that are captured in the WESPs are collected on the inside of the tube walls. The solids are washed from the tubes using a low pressure flushing system that uses weak acid. However, on the primary WESPs, the solids form very hard buildups that are very sticky to the tube walls cannot be washed out during the normal flushing. When the build-ups grow, they interfere with the operation of the units by high frequency of flashovers. The affected WESPs transformer PLC then automatically reduces the power supply to the unit to maintain the flashovers within safe limits, this reduces the dust and mist capturing efficiency. The change is observed through the trends when the power input is reduced.

The WESP train has to be stopped and the build-ups are cleaned out manually. The cleaning is laborious but eventually after cleaning the WESPs performance improves and cleaning efficiency is maintained.

Cleaning quench tower ring pipes and nozzles during shutdown

The Isasmelt quench weak acid circulation system also requires periodical manual cleaning. The solids circulating in the quench with weak acid slurry gradually build-up on the inside of the pipe walls then cause blockages (Fig. 4). The worst affected are the horizontal rings above the quench which distribute liquor to the nozzles. The cleaning can only be done when the Isasmelt off gas system is offline. Hence to manage this situation, the lines are opened up and cleaned in advance before the blockages become severe. This activity is always included in the scheduled shutdowns and also on all the opportunity shutdowns on the Isasmelt.

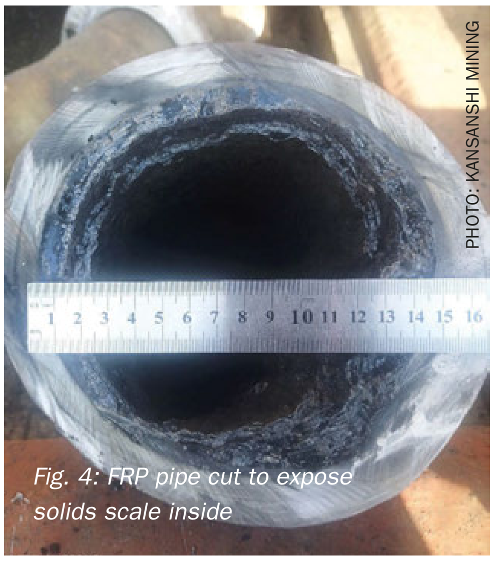


Fig. 4: FRP pipe cut to expose solids scale inside

Sodium silicate dosing based on plant assays

Sodium silicate is dosed at the PGCTs to remove fluorine from the off gas before the catalytic converter. The amount of fluorine in the off gas is variable based on the mineralogy of the concentrates smelted in the Isasmelt. During the times when the concentrations of fluorine are very high the dosage of sodium silicate is increased while monitoring the residue fluorine in the strong acid which should be maintained below 1.0 ppm. When the concentration of fluorine is low, the dosage is gradually reduced and sometimes turned off as long as the fluorine concentration in the strong acid remains below 1.0 ppm. Excessive sodium silicate in the weak acid system can cause operational problems because it tends to precipitate and then blocks the plate heat exchangers that are used to cool the weak acid. Currently there is no online system to monitor the fluorine in the system, the assays are obtained from manual samples which are collected every shift.

Field operator's routine checks

There are some routine activities that have been designed for the field operators to keep them engaged with the process. The operators collect readings from the instruments that do not show on the DCS such as HES pumps suction and discharge pressures, plate heat exchangers water side inlet and outlet pressures and WESP band heaters temperatures. The data are recorded at regular intervals in a manual log sheet by the control room operator and then recorded in the process historian at the end of the day. The data is then available for trends and other analysis. The routines are also helpful in capturing information that cannot be measured by the instruments such as acid leaks from flanges, blocked nozzles etc.

Gas cleaning plant maintenance

Apart from good operation practices, the maintenance strategies on the gas cleaning plant have to be good to achieve high plant availability. Some of the important maintenance strategies that have been implemented at Kansanshi are highlighted below.

Standby units on the HES and PGCTs

All the HES and the PGCTs have two independent circuits for the circulating weak acid. Each circuit supplies sufficient liquor to quench the incoming gas and keep the outlet gas temperature below the high limit. In normal operation, both circuits are always online and the gas source will be tripped out if one of the circuits is offline for more than 30 minutes. There is also a third pump on each unit that can be connected to either circuits as standby pump, therefore any of the circulation pumps can be taken out for maintenance while the plant is running. In the same way, the PGCTs have standby heat exchangers that allow for maintenance while the plant is online.

Change to more suitable materials of construction

Some areas of the gas cleaning have been changed to different materials of construction because of high rates of corrosion. For example, intermediate blower on the Isasmelt off gas route had a shaft and a casing that were originally made of rubber-lined mild steel while the impeller was made of a duplex stainless steel. Because of weak acid attack on both the rubber and the steels due to presence of high concentrations of HCl and HF, all the parts of the blower were changed to super duplex steel and the rubber linings were removed. Similar problems were experienced on the Isasmelt quench tower where weak acid was percolating through bricks and mortar to the mild steel shell and corroding it, the steel on the tower shell was changed to stainless steel. The Isasmelt scrubber cone was also made of rubber-lined mild steel originally but was changed to stainless steel after high rate of corrosion. The introduction of corrosion resistant steels eliminated the need for frequent maintenance on the equipment.

HES maintenance during PSC turnaround

When a PSC is taken offline for turnaround maintenance, the associated HES and intermediate blowers are also taken for extensive maintenance. The turnaround period is about three weeks which gives enough time for thorough checks on the HES which include refractory inspections and repairs, instrumentation calibrations, mechanical repair of all the pumps and the hydraulic system for the throat damper. The intermediate blower casings are opened up and impeller washed with pressure washer. All major overhaul maintenance is carried out during this period therefore during normal acid plant shutdowns there are no jobs to do on the converter off gas routes which free-up a lot of the resources to other areas.

Acid plant operations

The operations in the acid plant are also critical to ensure high plant availability and to extend the catalyst life. Some of the acid plant operating strategies are presented below.

Strict control of the acid concentration

The acid concentrations of the drying tower and absorber towers systems are maintained strictly at the setpoints of 96% and 98.5% respectively. On each system there are two online analysers for comparison during continuous operation. Each of the two online transmitters can be selected for control thus there is no lost time if one of them becomes faulty. In addition to the two online measurements, the operators collect two-hourly samples from both systems which are analysed in the field lab using an ultrasonic analyser, the results are recorded in the process historian for trends. At the end of every shift a sample of the acid from each circuit is taken to the smelter laboratory for check using a titration method. All these methods of counterchecking are done to make sure that the instruments are always reading correctly and any weak acid formed in the system is detected quickly.

Highly automated pressure control system

A feed forward control system was implemented to protect the SO_2 converter from surges in pressure arising from situations such as the rolling-in and rolling-out of the PSCs. The pressure protection overrides the temperature control logic by opening the dampers in the area to ensure that the gas paths are open to allow the pressure surge to pass. The details of the pressure logic are described by Ng'ambi[5].

Highly automated temperature control

The SO_2 converter temperature control is highly automated. It is always necessary for the temperature control dampers (TCVs) to be adjusting their positions in reaction to changes in gas flow rates and changing SO_2 concentrations. The TCV positions are adjusted automatically by temperature control logic to maintain the setpoints. Operator interference is minimised and the plant recovers more quickly after flow disturbances when PSCs roll in or out. The TCVs also play an important role in holding heat inside the converter during prolonged shutdowns, the converter can hold the heat for up to three days without requiring the preheater for start-up.

High detail temperature monitoring

Each converter bed has more than one thermocouple installed on the inlets and outlets. Bed 2 and Bed 3 each have a total of four thermocouples, two for the inlet and two for the outlet, while Bed 4 has a total of six thermocouples with two extra thermocouples installed in the middle of the bed. The thermocouples are installed 180° apart. On Bed 1 there are a total of 18 thermocouples, six at each level, inlet middle and outlet.

Highly automated SO_2 concentration control system

The feed gas SO_2 concentration and volume are controlled by a feed forward system. The total SO_2 flow in from the Isasmelt furnace is calculated from the concentrate feed rate and the concentrates blend SO_2 factor. The SO_2 gas from PSCs is calculated from the blowing rate of the particular converter and empirical SO_2 factors for copper blow mode and for slag blow mode. The total gas flow from each SO_2 source is calculated from the motor current not speed and pressure drop of the intermediate blower in that route.

The dilution air required is calculated from the calculated SO_2 in feed gas as described above and the target setpoint selected by the control room operator.

There is a venturi-type flowmeter to measure the flow of the feed gas and compare to the feed forward calculations. The SO_2 concentration is also measured by an online analyser to check the predicted concentration from the calculations. Oxygen concentration in feed gas is also measured online to check that it is sufficient for the conversion reactions.

The control room operator is able to manipulate the system using an adjustment calculation if they observe that there is deviation of the predicted SO_2 concentration calculation against the analyser readings. The plant safety limits are configured in the DCS to prevent operator actions that would be dangerous for example the maximum gas flow to the plant is limited to 330,000 Nm^3/h and the DCS prevents actions that would cause the flow to exceed this number.

Operator routine checks

Within the oxidation area and strong acid area, monitoring acid condensation in equipment and ducting on regular intervals is important. This assists in identifying the cold areas in the plant and works as one of the tools to monitor the efficiency of the filters at absorption and drying tower gas outlets.

The field operators check drain points at different points in the ducting, the gas-gas heat exchangers, SO_2 blower suction and stack for condensate formation at least once per shift. The areas where acid condensate have been found more often are checked on more frequent intervals. Any condensate formed is drained into stainless steel buckets and discarded into the strong acid area sump. The volume of condensate collected from each drain point is recorded in the shift log.

The cold re-heat exchanger drain points have a high rate of condensate formation; hence the condensate is drained more frequently than from other collection points. In order to reduce manual handling of acidic condensate, the drained acid is transported in a pipe by using compressed air to a tank located within strong acid area. The level of the tank is monitored in the DCS and the level change per shift is recorded.

Maintaining a robust water treatment programme

Water treatment is very important in maintaining high quality water to cool the strong acid during acid absorption and also to cool the weak acid circulating at the PGCTs. Acid plant cooling water is cooled in an open cooling tower and raw water from rivers is used as make-up. The cooling water system is chemically treated using biocides, antiscalants and corrosion inhibitors to prevent corrosion of pipes and scaling of calcium. Part of the product sulphuric acid is dosed to the cooling tower to maintain the pH of the water within the targeted range.

Previously the water quality was poor which caused calcium scales to form in the acid coolers. The acid coolers started to have leaks on the same tubes that had scales. The plant was stopped frequently for long hours to plug the leaking tubes. One of the acid coolers was significantly damaged and had to be replaced.

The water treatment was contracted to a specialist with a more robust treatment programme and enhanced monitoring of the water quality. After the change, the scaling in the coolers was eliminated and there has not been reoccurrences of acid leaks on the coolers for more than five years of operation.

Strict control of acid temperatures and anodic protection on all acid coolers

All the acid coolers are made of stainless steel and have anodic protection systems. However, the acid temperature to the cooler must be below the maximum temperature limit to avoid corrosion. The most common scenario that leads to high acid temperatures is when there is a very high concentration of SO_2 in the feed gas leading to a surge of SO_3 coming to the absorption towers also causing a surge in the heat generated in absorption and dilution. Acid temperature warnings and trips have been set much lower temperatures than the safe limits. Therefore, the control room operator has enough time to check and make adjustments to the process before the temperatures reach unsafe regions.

Acid plant maintenance

Below are some of the maintenance strategies for maintaining high availability in the SO_2 converter and strong acid sections.

Condition monitoring

All the major equipment in the acid plant have online instruments installed to monitor vibrations, pressures, temperatures etc. The data is recorded in the process historian for trending and analysis. In addition, a reliability engineer performs scheduled checks on the equipment in more detail with more sophisticated tools and keeps the data in separate database for analysis. Condition monitoring reports are sent out every two weeks to both operations and maintenance teams so that maintenance planning is always in line with operations planning.

Standby acid pumps

All the strong acid circulation and the product pumps have standby units installed, pump swap can be done online without shutting down the acid circulation system. In addition to that, there are fully assembled spare acid pumps kept in acid plant for quick pump change when there is an opportunity. The same type and size of acid circulation pumps are used for the drying tower and the absorption towers hence only one spare pump of this type is kept while a different spare pump is required for the product acid pump which is smaller.

Carefully planned shutdowns

The smelter has a scheduled shutdown every three months for all major maintenance works. Planning is critical to ensure that the shutdowns do not overun. All the disciplines and all the sections of the smelter are involved in the planning of the shutdowns and several meetings are held to discuss all the shutdown jobs to align and highlight all the resource requirements. A dedicated shutdown planner makes the final schedule which is followed during the shutdown.

Turnaround shutdowns are planned in a similar way with all disciplines involved and resources pooled together. More time is required to plan, all the major works have to be submitted at least one year before. The shutdown budget is also approved one year in advance which gives enough time for procuring the long lead items. Pre-shutdown activities planning and tracking is also part of the shutdown planning, the last months before shutdown are dedicated to pre-shutdown activities so that only activities that require the plant to be offline will be focussed on during the shutdown.

Strategic stock on site for all major plant equipment

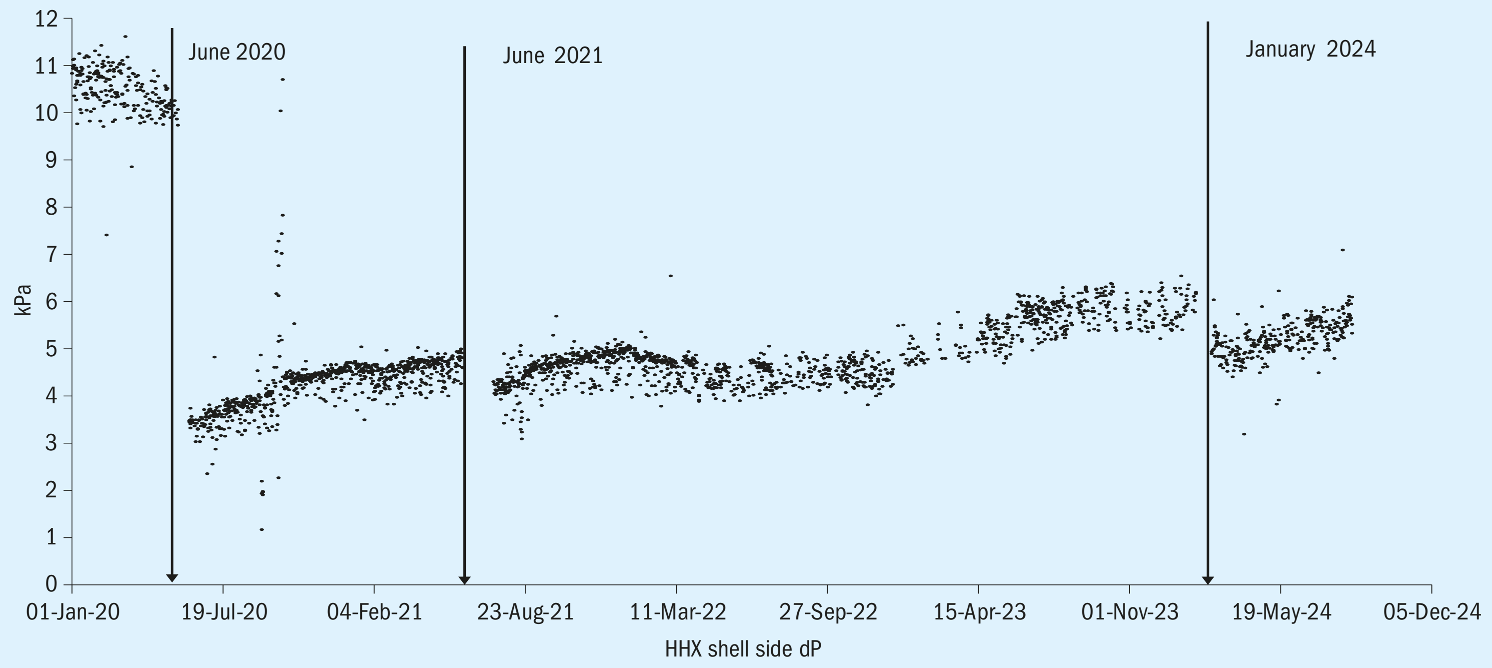
The smelter keeps a strategic stock of the majority of the major equipment on site. Some of the equipment are long lead items and take several months to reach site when ordered while others are fast consumed components. A strategic stock ensures that there are no major shutdowns when an equipment fails.

Challenges

Hard scale forming in the Isasmelt quench weak acid pipes

The solids build-ups in the FRP pipes at the quench tower form a hard scale that is difficult to remove. To clean out the scale, the pipes have to be opened up on flanges and sometimes the FRP has to be to be cut to expose all the bends and corners. Sharp tools like steel bars are used to break the scale, since using a high pressure water gun does not break the scale. Apart from blocking the lines, the scales also block the strainers on the suction side of the acid circulation pumps leading to low currents and low flows and line blockage. Frequent cleaning of the pipes and the strainers is required sometimes causing downtime on the smelter.

Fig. 5: **Hot heat exchanger pressure drop and cleaning**



Source: Kansanshi Mining

An antiscalant chemical is dosed in the weak acid to make the scale softer when cleaning but it still doesn't prevent the high number of stoppages to clean the build-ups.

WESP tubes cleaning

The cleaning of solids in the WESP tubes is also very challenging similar to what is experienced with the quench tower solids. The solids form hard scales that cannot be removed during flushing of the WESPs. The scales are found mostly on the top half of the primary WESPs. This is where most of the dust is trapped during operations. Hydroblasting is also not very efficient in removing the scales. Cleaning the tubes with hand tools is difficult because there is limited head room to manoeuvre around. The tubes are narrow and long hence long tools are needed and the electrodes in the centre of the tubes obstruct the movement of any tools. Sharp tools cannot be used for cleaning because there are some electrical connections that are imbedded in the FRP tubes that could be damaged while cleaning. Similarly, hydroblasting machines have to be used carefully because the high pressure can break the tubes and electrical connections.

Fig. 6: Cleaning scale on the hot heat exchanger

High pressure drop on the hot heat exchanger

The hot heat exchanger frequently gets high pressure drop on the shell side (Fig. 5). This is caused by metal flakes that peel off from the pipes surfaces also by catalyst dust that builds up on surfaces and forms flakes. The high pressure drop causes feed restrictions.

Cleaning of the tubes is difficult because of the restricted space between the tubes. Special knife plates were made to be used for cleaning however the reduction in the pressure drop after cleaning has not been very consistent (Fig. 6).

Power failures

The smelter experiences power failures and power disturbances several times every month. Power disturbances occur when there is high fluctuation in the supply voltage which trips out several equipment. Supply failure occurs when the power supply is completely cut off because of a fault at the utility company. The high frequency of these power disturbances and failures has a negative impact on the smelter availability.

Conclusions

The improvements in the acid plant campaign from two years to four years has been due to continuous improvements in many areas. The high availability of the plant is also due to strong commitment to good operations and maintenance practices. ■

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Producing sulphuric acid from gas streams with variable SO_2

The first installed combination of a regenerative SO_2 scrubbing system with a sulphuric acid plant using Worley Chemetics' CORE™ reactor technology started up in November 2022. The combination of these technologies allows production of high-grade sulphuric acid from gases with low and/or fluctuating SO_2 concentrations. **C. Trujillo Sanchez** and **R. Dijkstra** of Worley Chemetics report on the design concepts of this integrated process, highlight where it is most effective and report on the start-up and first years of operation of the plant.

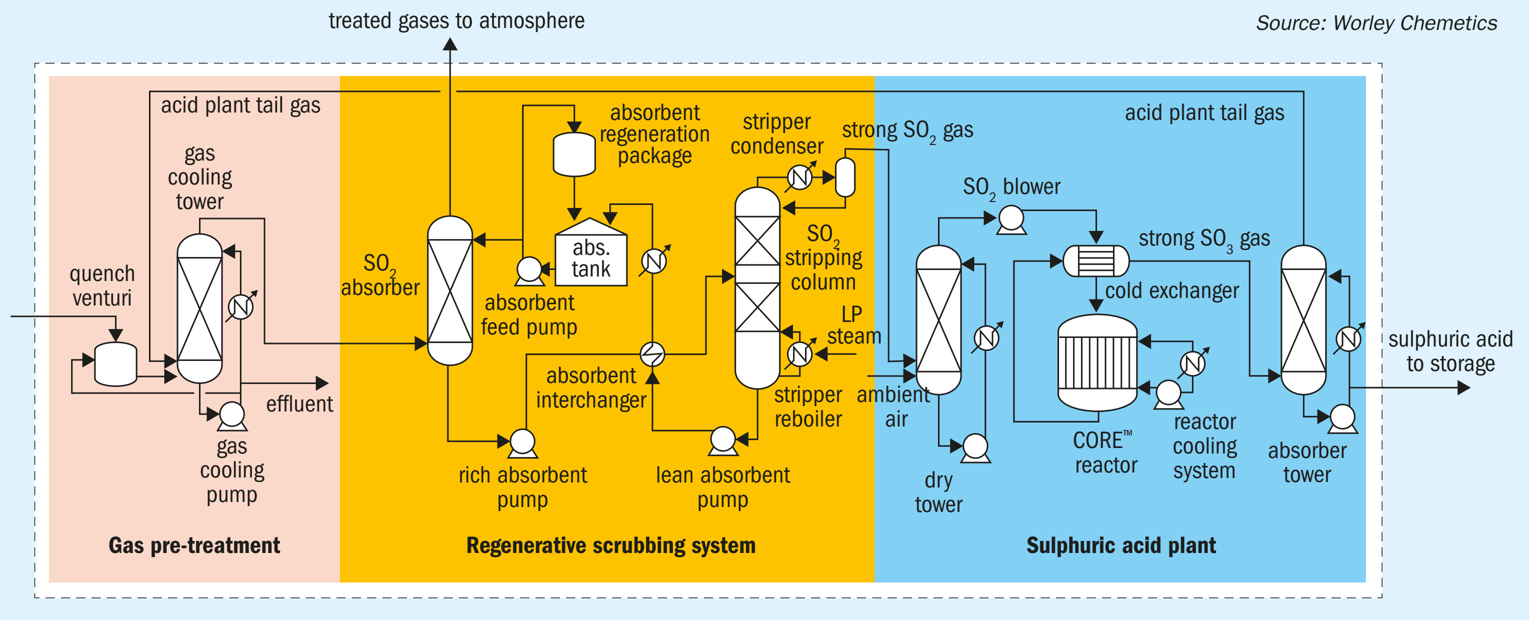
Jambaran Tiung Biru site.

The management of sulphur dioxide (SO_2) emissions is a critical concern for various industrial sectors. SO_2 emissions arise from the combustion of waste gases containing hydrogen sulphide (H_2S) within the oil and gas sector. Additionally, the metallurgical industry contributes to SO_2 emissions through off-gases that exhibit varying concentrations of this pollutant. A notable challenge faced by both industries is the fluctuation in SO_2 levels in their emissions, which is influenced by the composition of their source materials.

The variation in SO_2 concentration presents a significant challenge for the conventional production of sulphuric acid using the double contact double absorption (DCDA) process. This process requires mixing SO_2 with air to achieve a concentration between 5% and 13% by volume and an O_2 to SO_2 ratio above 0.9. The mixed gas is then directed through adiabatic catalyst beds, with gas heat exchangers installed after each bed to cool the process gas before further reactions occur. If the SO_2 concentration is too high, the temperature in the first catalyst bed can exceed the safe limits for vanadium pentoxide, leading to irreversible damage to the catalyst. Conversely, if the SO_2 concentration is too low, the plant falls below its autothermal threshold and catalyst temperatures cannot be maintained, resulting in a significant reduction in the conversion of SO_2 to SO_3 or need for supplemental fuel which increases operating cost. This inefficiency may prevent the plant from meeting environmental emission standards or lead to excessive operating costs. Low SO_2 concentrations also result in a rapid increase in size of the DCDA acid plant leading to high capex.

A solution for applications where the SO_2 content is too low to allow direct conversion in a DCDA process is the CORE-FGD™ (CORE process for Flue Gas Desulphurisation) process offered by Worley Chemetics. This system provides a versatile and cost-effective solution for gases with low and/or fluctuating SO_2 concentrations, with the further benefit of reduced plant size and operational versatility of the CORE™ technology.

Fig. 1: **CORE-FGD™ process**



Source: Worley Chemetics

The CORE-FGD™ process

The CORE-FGD™ process produces sulphuric acid utilising three main process sections:

- Flue gas pretreatment
- Regenerative SO_2 scrubbing
- Sulphuric acid production

Fig. 1 shows a simplified schematic of the three main sections. The combined process provides a versatile platform that can be easily adapted to fluctuating inlet SO_2 concentrations and/or varying flue gas characteristics. Due to the customisable flue gas pretreatment system and the regenerative scrubber a virtually pure SO_2 gas stream is produced that is efficiently converted to sulphuric acid. Additionally, due to the benefits of the CORE reactor technology the plant footprint and equipment count is significantly reduced compared to a conventional acid plant. It should be noted that all process sections can be provided as a single package by Worley Chemetics allowing the most suitable solvent licensor to be used for the project.

Gas pretreatment

The gas pretreatment section can be customised to handle any contaminants contained in the incoming gas. Generally, a quenching step as shown in Fig. 1 is required to create a cool saturated gas. However, much more elaborate gas cleaning systems may be required if the off-gas contains dust, metal fumes, halogens or other undesired components. If these impurities are not effectively removed, they may contaminate the scrubbing solution and/or lead to fouling in the scrubbing system. In these cases, the feed gas is conditioned in a gas pre-treatment system tailored to the specific impurities present in the feed gas. In the case of the oil and gas industry, where sulphur containing waste gases are created, the waste gases are first passed through a thermal oxidiser or incinerator to convert oxidise the hydrocarbons to CO_2 and the H_2S and other sulphur species to SO_2. After the incinerator, the gas is cooled to recover valuable energy and is quenched/scrubbed to remove particulates and other impurities. Finally, the gas is passed through mist eliminator candles to remove sulphuric acid mist.

Regenerative scrubbing

The regenerative scrubbing system is designed to capture the SO_2 from the gas and delivers the captured SO_2 as a highly concentrated SO_2 product stream. This makes it particularly suitable in situations where SO_2 gases exhibit significant variability in concentration and/or are too diluted for direct processing in a sulphuric acid plant. The gas leaving the pretreatment is directed through an absorber, where it interacts with an SO_2-selective solvent (typically an aqueous amine solution). After absorption, the treated gas, with the SO_2 removed by the amine, can be safely released into the atmosphere. Subsequently, the SO_2-enriched amine is routed to a stripping column, where it undergoes regeneration via steam stripping. The gas emerging from the stripper is recovered as pure SO_2 stream, saturated with water.

It should be noted that the regenerative scrubbing system can also include a second absorber column to capture CO_2 which can be recovered as a separate stream for sites looking at carbon capture. In this case the removal of SO_2 is a prerequisite for obtaining a pure CO_2 product.

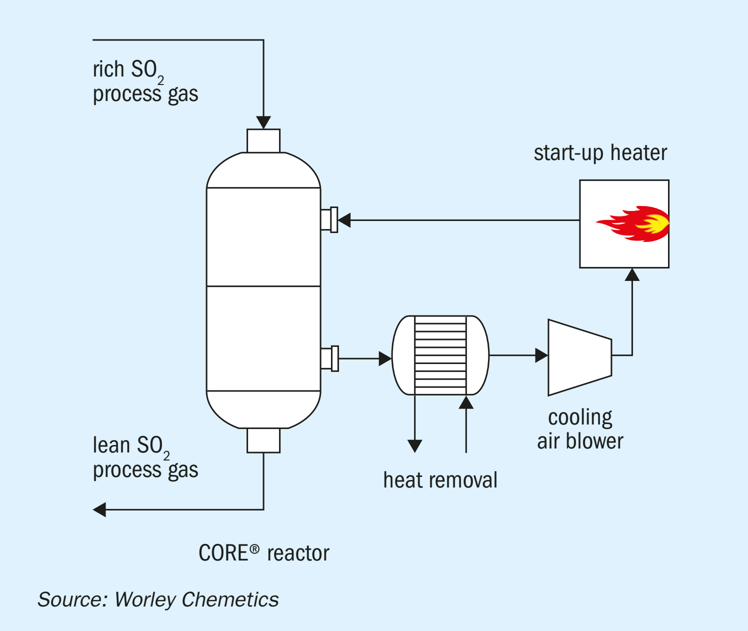
Sulphuric acid plant

In the sulphuric acid plant process, the SO_2 gas from the regenerative scrubbing area is converted to SO_3 to produce acid. Oxygen (ambient air, oxygen enriched air or pure oxygen) is added to gas from the regenerative scrubber to provide the oxygen necessary for conversion of the SO_2 to SO_3. The gas is then dried in a drying tower. If air is used to provide the oxygen then a dry gas is created with approximately 19 vol-% SO_2 which is passed through a heat exchanger to increase the gas temperature and enters the CORE™ reactor to produce SO_3.

CORE™ reactor

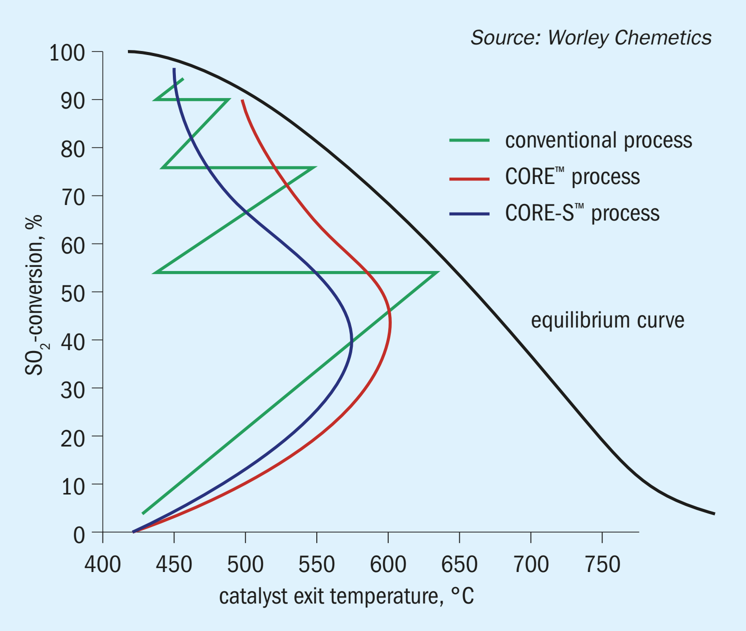
The CORE™ reactor is a tubular reactor with tubes containing a vanadium pentoxide catalyst. The tubes are continuously cooled on the exterior with a cooling medium (salt or air), maintaining the reaction temperature in a narrow range under all operating conditions. Fig. 2 shows the basic operation of a CORE™ reactor with cooling air. Cooling air is directed over the exterior of the CORE™ using a blower. During start-up, when the system is cold, a start-up heater is used to preheat the catalyst with circulating air before introducing process gas or during hot standby. As the reactor begins generating heat, the cooling air warms up and

Fig. 2: **CORE™ reactor with cooling air**



Source: Worley Chemetics

Fig. 3: **SO_2 conversion vs gas temperature**



must be cooled before being recirculated into the CORE™. This creates an opportunity for energy recovery. Large reactors are designed with molten salt cooling instead, which is more compact and consumes less power for coolant recirculation.

Because of this continuous cooling, the reactor can achieve single pass conversions of up 97% and operate with feed SO_2 concentrations between 0 to 20 vol-% using air as the diluting medium, or between 0 to 60 vol-% when using pure O_2 as a diluting medium. Fig. 3 shows the difference between the conversion of the conventional acid plant, CORE™ (air cooled), and CORE-STM (salt cooled). Molten salt temperatures increase slower as compared to air due to the higher energy density of molten salt, resulting in higher conversion rates. If the unconverted SO_2 (and O_2) can be recycled it is beneficial to design the reactor with lower single pass conversion as this reduces overall cost.

The energy in the hot reactor outlet gas is recovered by preheating the incoming feed gas. This dual-purpose heat exchange enhances energy efficiency and results in a safe entry temperature into the absorption tower. The cooled gas passes through the absorption tower, where essentially all the SO_3 in the gas is removed by absorption in sulphuric acid. Since a single pass through the CORE™ can achieve up to 97% conversion, this is generally not sufficient to achieve environmental limits. Therefore, the gases leaving the absorption tower are directed back to the gas pretreatment to cool the gas and remove the unconverted SO_2 in the regenerative scrubbing system. This also has the advantage that there is only one discharge location for the process that requires permitting. The regenerative scrubbing system can be designed to meet local environmental requirement and can discharge as low as 50 mg/Nm³ without further treatment.

Energy recovery within a CORE-FGD™

Within the CORE-FGD™ system there are opportunities for energy integration and/or energy export. Generally, the regenerative SO_2 scrubbing system will be the main user of thermal energy (low pressure (LP) steam) whereas excess thermal energy is available from the sulphuric acid plant and the gas pretreatment area. In the gas pretreatment, heat exchangers can capture usable energy from the hot feed gas stream. Condensing heat exchangers have been successfully used to maximise energy recovery. The sulphuric acid plant has excess energy from the exothermic reactions involved in converting sulphur dioxide (SO_2) to sulphuric acid. This energy can be advantageously captured as LP steam and used in the regenerative scrubbing system although production of HP steam is also possible. The energy requirements in the regenerative scrubbing system can be reduced by re-using the energy from the stripping column overhead stream. Mechanical vapour recompression has been successfully applied and can reduce the energy required in the regenerative SO_2 scrubbing system by over 75%.

First CORE-FGD™ plant project

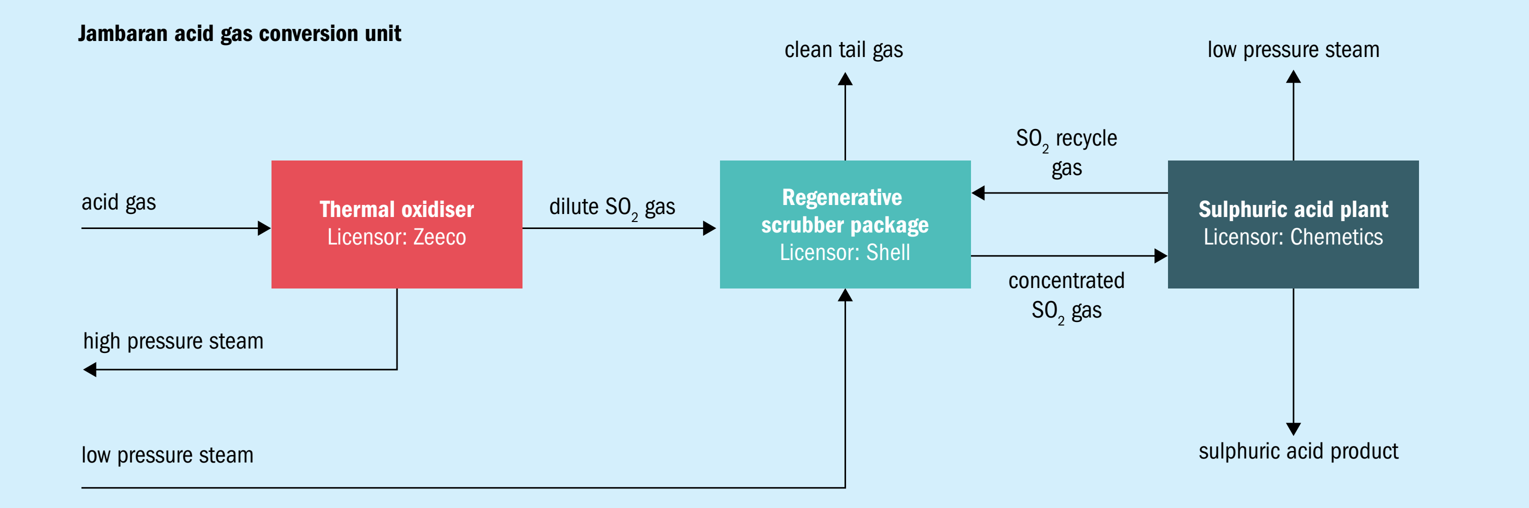
In 2017 Shell Global Solutions, working together with Zeeco and Worley Chemetics, signed a contract with Pertamina EP CEPU (PEPC) for the supply of a process design package (PDP) and critical equipment for a CORE-FGD™ system for the Jambaran Tiung Biru (JTB) gas processing facility in East Java, Indonesia. The JTB site is a gas processing facility for sweetening and compression of raw gas from six new sour gas wells in the area and has a design capacity of 192 million std. ft³/d. After extensive reviews, PEPC selected the Selexol process for the acid gas enrichment unit and decided that the acid gases from the Selexol unit would be converted into energy (steam) and sulphuric acid. At full capacity the acid gas contained enough sulphur species to produce approx. 377 t/d sulphuric acid. The sulphuric acid produced was to be sold to a nearby sulphuric acid user.

The project was completed in two phases. The first phase, completed in 2018, consisted of the PDP/basic engineering package for the entire acid gas unit that would allow PEPC to obtain firm pricing for the equipment. The acid gas conversion unit consists of three packages as indicated in Fig. 4:

- Thermal oxidiser: Waste gas incinerator c/w dual HP steam boilers.
- Scrubber package: Incinerator gas pretreatment (quench / mist removal) + Shell Cansolv© regenerative scrubber system.
- Sulphuric acid unit: Sulphuric acid plant using CORE™ technology.

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 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48

Fig. 4: Acid gas process for the JTB project



Source: Worley Chemetics

Table 1: **Design requirements for the JTB CORE-FGD™ facility**

Facility Type	Sour gas facility – Acid gas from Selexol process
H_2S content in sour gas, vol-%	0.32 – 0.48
SO_2 content to Cansolv system, vol-%	1.8 – 3.8
Expected acid production, t/d (based on gas well H_2S surveys)	330
Design sulphuric acid production, t/d	377
Emissions (from Cansolv stack), ppmv	≤ 200
Design feed SO_2 concentration to CORE™, vol-%	18.9
Design conversion in CORE™	90%

Source: Worley Chemetics

The second phase saw PT Rekayasa Industri (Rekind) commence as the overall EPC contractor for the entire gas processing facility in 2019. In 2020, Rekind awarded the engineering and procurement (EP) contract for the sulphuric acid unit to Worley Chemetics/ PT Enviromate Technology International on a lump sum basis. At the same time, Zeeco was contracted to supply the incinerator package and Shell Global Solutions delivered the proprietary equipment for the Cansolv regenerative scrubbing system. Detailed design and supply of the balance of materials, as well as the overall integration of the three packages was done by Rekind.

The target start-up date for the gas processing facility was mid 2021. Similarly to many other projects, the COVID-19 pandemic caused delays. After a brief shutdown of the site in early 2020, construction re-commenced, and raw natural gas from the first production well was introduced into the facility in July 2022. Commissioning delays on the acid gas enrichment unit (Selexol) meant that the first acid was not produced until early November 2022.

Sulphuric acid plant design

Table 1 summarises the site design criteria for the sulphuric acid plant. With a sour gas application with variable feed H_2S content, a CORE-FGD™ with an air-cooled CORE™ reactor was a perfect fit for this plant.

The key process design features included in the design of the plant were as follows:

- plant turndown between 20 and 100% capacity;
- autothermal sulphuric acid plant operation above 6% SO_2;

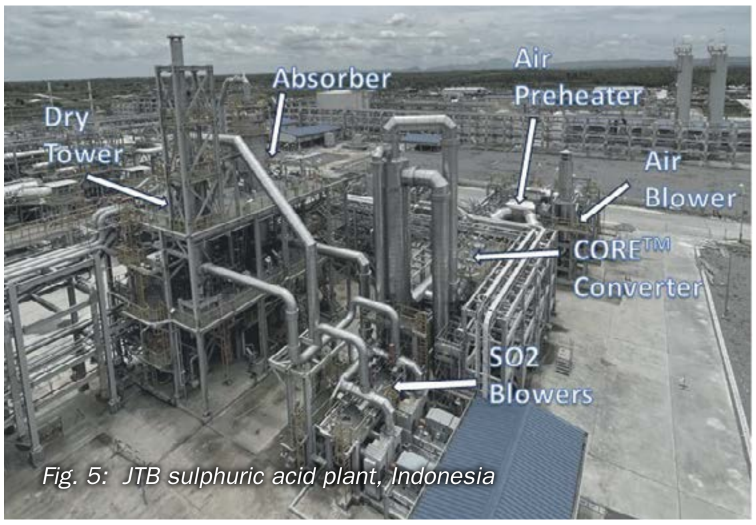


Fig. 5: JTB sulphuric acid plant, Indonesia

Fig. 6: CORE™ reactor top vestibule

IMAGES: WORLEY CHEMETICS

Table 2: **JTB CORE™ Acid Plant Performance 2022-2024**

Gas operating range, %	15 to 90
Acid production range, %	10 to 80
Single pass conversion achieved, %	90 to 97
Single pass guaranteed conversion, %	≥ 85

Source: Worley Chemetics

- dual (duty and standby) SO_2 blowers and cooling air blowers to comply with site requirements;
- hazardous area classification for entire plant due to location in gas processing facility;
- electric preheat system to enable plant start-up without need for hydrocarbon fuels;
- variable speed drive for blowers to reduce power consumption;
- SARAMET® alloy towers and piping;
- energy recovery from CORE™ reactor producing LP steam;
- ability to remain in hot-standby for an unlimited period, ready to receive SO_2.

Fig. 5 shows the compact design of the CORE™ acid plant, highlighting the relatively small size of the CORE™ reactor compared to the rest of the facility. Fig. 6 shows the gas inlet vestibule of the CORE™ reactor with the tubes holding the catalyst clearly visible.

Sulphuric acid plant performance

Over the past two years, the plant has operated continuously and has produced sulphuric acid of high quality. Acid production has been lower than anticipated due to lower-than-expected sulphur content of the raw gas and upstream process issues. These upstream process issues resulted in prolonged operation at low rates and frequent process interruption that showcased the ability of the CORE™ reactor to remain in hot standby mode as its capability to operate at very low rates with ease. Table 2 show the some of the CORE-FGD™ process operating ranges for the past years. During this period the Cansolv© regenerative scrubber also met all environmental requirements for SO_2 emissions.

Conclusion

The CORE-FGD™ system has demonstrated its effectiveness as a versatile solution for managing fluctuating SO_2 concentrations in industrial emissions. By integrating flue gas pretreatment, regenerative scrubbing, and an advanced sulphuric acid production process, the system offers excellent operational flexibility and efficiency, even under challenging conditions such as the variable gas flows and low SO_2 feed concentrations experienced at the JTB site.

The compact design and advanced technology of the CORE™ reactor contribute to a small plant footprint and enhanced energy recovery. The CORE-FGD™ system's ability to reliably produce sulphuric acid at low operational costs and environmental impact, makes it an excellent alternative to conventional acid plants.

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