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

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SULPHUR

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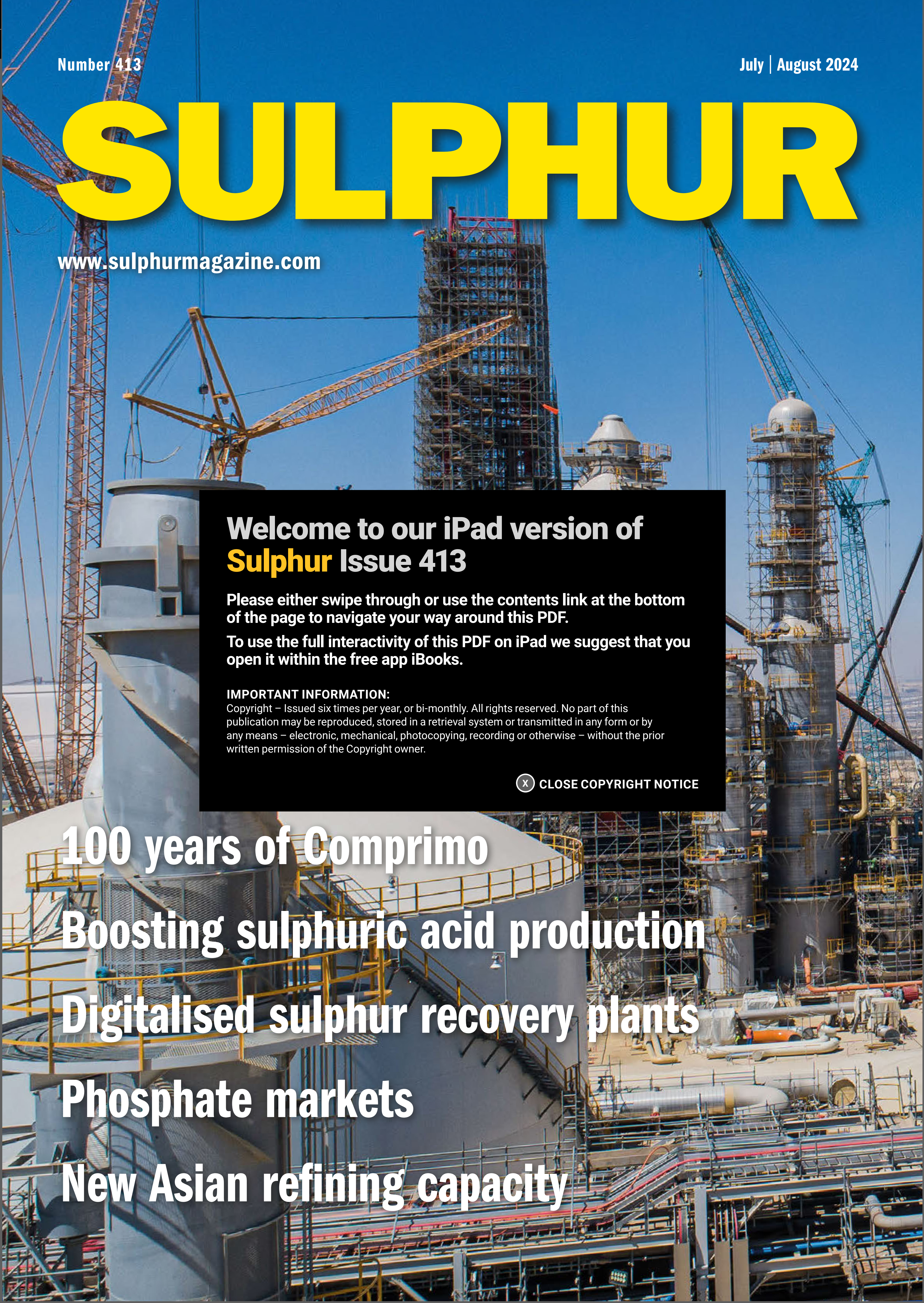

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100 years of Comprimo

Boosting sulphuric acid production

Digitalised sulphur recovery plants

Phosphate markets

New Asian refining capacity

Cover: *The Ma'aden 3 phosphate plant under construction.*
Photo: Ma'aden

Asian refining

New refinery capacity boosts sulphur output

Sulphur recovery technology

Comprimo celebrates 100 years

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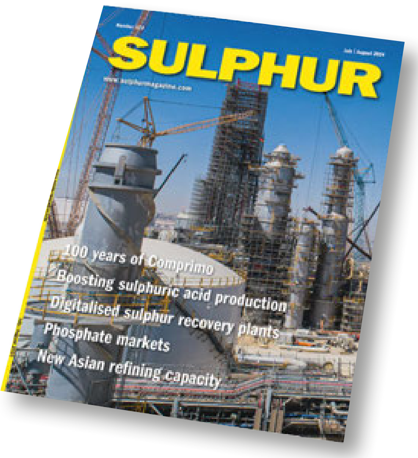
NUMBER 413 JULY | AUGUST 2024

CONTENTS

REGULARS

Europe's sulphur troubles



While the events of the past few years have been difficult for Europe on many fronts, including a wholesale realignment of its energy sources with the restriction of access to Russian oil and gas, the effect on Europe's sulphur production seems likely to be just as profound.

Europe has been a sulphur exporter for decades. It was one of the places where sour gas production was developed back in the 1950s, at Total's Lacq gas field in France, and has been a major refining region for even longer, with those refineries having to begin removing sulphur as environmental regulations tightened faster in Europe than elsewhere in the second half of the 20th century. It even maintains the world's last major working Frasch sulphur mine, at Osiek in Poland. However, production from all of these sources is shrinking rapidly, and within the next couple of years, Europe may well become a net sulphur importer.

> **"Within the next couple of years, Europe may well become a net sulphur importer..."**

To take those sources in turn; Europe's sour gas fields are depleted. Lacq was closed down in 2013, and the last major field, at Grossenknetten in Germany, is in decline. Sulphur output dropped another 90,000 t/a in 2023 to 280,000 t/a. While there are reportedly sufficient gas reserves to keep operating until around 2030, it is unclear when ExxonMobil will decide that the site is no longer profitable, and CRU estimates that the site will probably cease production around 2026-27.

On the refining side, European refinery throughput has been on a steady decline since 2015. An ageing population and increased focus on long distance rail travel, as well as efficiencies in car fuel consumption have all played their part, but the post-covid move to home working and the rapid switch towards electric vehicles have speeded that transition in recent years. German diesel consumption fell by 10% from 2019-2023, for example. The switch away from Russian crude feedstock has cut supplies to some refineries in central and eastern Europe, while others face competition from cheap imports from the Middle East and US. Refineries are closing or converting to biofuel production. Sulphur production from Europe's refineries totalled 3.3 million t/a in 2023, and this is forecast to fall to 3.1 million t/a in 2024.

Finally, while the Siarkopol sulphur mine continues to operate, production there has fallen too this year, significantly below the operating average for the past decade. Output in January to May 2024 totalled 130,000 tonnes of sulphur, with the full year figure likely to be around 390,000 tonnes, against a usual annual average of around 480,000 t/a.

Set against this, demand has also declined, with caprolactam production particularly weak. Nevertheless, demand seems to have bottomed out for now, and may recover back towards 4 million t/a by 2028, by which time European demand will have outstripped supply. The answer will be to import sulphur, but the European market is very much geared towards liquid sulphur, and so to source sulphur from e.g. the Middle East will require new sulphur remelter projects. There are currently two major projects under discussion. Saconix and its partner LogServ Logistics, have designed a proposed sulphur import terminal for the port of Brake at the mouth of the Weser river in northwest Germany. The sulphur remelter would have a capacity of 300,000 t/a. Meanwhile Aglobis announced plans in 2020 for a sulphur logistics terminal and remelter, in partnership with Savage Services and the inland port of Duisburg, on the Rhine river. This remelter would have a capacity of 400,000 t/a. However, time is starting to run short – even if greenlit today, the earliest likely start-up of these projects would be in 2026-27.

Richard Hands, Editor

Price Trends

SULPHUR

Sulphur prices in China are expected to recover with downstream demand anticipated to surge in the second half of the year and good affordability to support raw materials purchasing. Chinese nitrogen, phosphate, and potash prices have surged, driven by heightened demand for the summer corn application season. In particular, average 11-44 MAP prices jumped 16% from $390/t ex-works to $463/t in Hubei province. However, sulphur prices have taken a while to follow the trend on phosphate prices. Port prices have fluctuated in the range of $126-130/t c.fr since late March, and import prices fell from a high of $112/t c.fr to $100/t c.fr, capped by high port inventory and sufficient supply. Port inventories in China remain around 2.8 million tonnes, well above the 2022 average of 1.4 million tonnes and the 2023 average of 2.07 million tonnes. These elevated stock levels limited the upside for prices in China and provided buyers with options. At the start of July, Sinopec's Puguang, the largest sulphur producer in China, increased its sulphur sales prices at Wanzhou port up $4/t RMB980/t, while its factory price at Dazhou was up RMB20/t at RMB950/t ex-works. These prices are considerably down from RMB1,600/t in December 2022 and RMB 2,945/t from mid-June 2022 and are the lowest since July 2023, but are still up from a low of RMB605-655/t at the end of August 2020.

Kazakhstan's Kashagan oilfield has faced government pressure to reduce its sulphur stocks, and crushed lump supply from the site is adding to market length, though lower stock levels should ease this pressure later in the year and sales of additional volumes from stock are expected to slow.

In the Middle East, new project commissions and expansions accelerated last year, with producers adding considerable volume. Much of the new capacity can access the market with low logistics costs, adding to the market surplus. There are fewer capacity additions to come in 2024 and demand is expected to catch up with supply by next year. Kuwait Petroleum Corporation (KPC) posted its official monthly price for sulphur exports, the KSP (Kuwait Sulphur Price), at $80/t f.o.b. for July, up $2/t from June. Total sulphur capacity in Kuwait is estimated by CRU to have climbed to 2.9 million t/a in 2023; up from 1.4 million t/a in 2020.

Elsewhere, in Qatar, Muntajat's latest sales tender was believed to have sold at close to $85/t f.o.b. in the UAE, ADNOC is understood to have completed negotiations with OCP in Morocco and GCT in Tunisia over Q3 sulphur. ADNOC has settled contracts with traders for sulphur supply from the Middle East in the third quarter of 2024 around $79/t f.o.b. Saudi Arabia has been selling crushed lump from stockpiles alongside its new production. Overall the Middle East spot price was assessed at $80-83/t f.o.b., up from $75-80/t f.o.b. earlier in June.

On the demand side, sulphur demand in Indonesia for nickel is set to increase further following a big jump in imports since 2022, limiting possible downside to global spot prices. Still, some of this demand may be met with increased domestic smelter acid output. The spot price assessment for sulphur cargoes to Indonesia was up modestly at the end of June to $102-105/t c.fr. PT Lygend's tender on the 19th June for 100,000 tonnes of sulphur was reported to have been awarded at $102/t c.fr. The importer is understood to have purchased two cargoes, with one potentially from Shell in Vancouver. Petro Jordan Abadi, a joint venture between JPMC and Petrokimia Gresik, closed a tender for 30,000 tonnes earlier in the month, with an award indicated around $103/t c.fr. Lygend had previously closed a tender on May 8th for 50,000 tonnes of sulphur, with the request reportedly covered around $107/t c.fr with supply from the Middle East.

Morocco's OCP has increased its fertilizer production in recent months and may ramp up further, though it has a range of options for sulphur supply.

In Europe, prices were relatively unchanged with a lack of buying and selling activity. Export prices were assessed steady at $75-80/t f.o.b. at the end of June, while the import range was at $95-105/t c.fr. Key markets in Egypt, Tunisia and Turkey were quiet apart from a domestic sales tender from Tupras in Turkey. Demand in Egypt from NCIC may also have taken a hit amid the country's ongoing natural-gas crisis.

Spot prices for sulphur cargoes to Brazil were assessed modestly higher at $103-105/t c.fr following two purchases by Galvani and Mosaic. Galvani's tender was understood to be for 30,000-35,000 t with Mosaic seeking as much as 40,000 t for August arrival at Tiplam in Brazil, which has been undergoing maintenance. Mosaic's tonnes are expected to load in the US Gulf. Mosaic's previous deal was a cargo of Middle East origin purchased in early May around $111/t c.fr. The buyer is reportedly covered until August now due to upcoming maintenance at the Tiplam terminal of Santos.

In North America, availability from Vancouver has been strong due to relatively high production at sites in Canada as well as re-melting of solid sulphur stocks. Supply from Canada is expected to remain strong, though current prices leave little incentive for sales from northern Canada, and stock drawdown will likely slow further. US availability is strong as refinery output is strong as the summer months approach, offering additional supply options for buyers west of Suez.

SULPHURIC ACID

Global spot prices are likely to remain relatively firm over the coming weeks. Strong Moroccan demand continues to add support to some benchmarks, with further support coming from Chile's return. Downstream production rates remain relatively weak overall and domestic acid production is set to increase in some key import markets, though this is more weighted to latter 2024. Affordability relative to downstream markets is broadly acceptable but looks particularly bad when compared with upstream sulphur.

Spot prices for sulphuric acid exports from China were assessed unchanged at $30–35 /t f.o.b. at the end of June, stabilising at this range. Sentiment in the Chinese phosphate market has improved over the past few weeks, with prices rising on the back of tight availability, while some increases in downstream production added support to domestic acid markets. Resistance from producers to lower export prices emerged partly as a result of higher prices available on domestic sales. Domestic prices continue to offer a premium over achievable f.o.b. prices for most producers, having increased sharply in recent weeks due to strong demand from MAP producers. Quarterly contract prices for supply to China were indicated settled around the low-to-mid-$20s/t c.fr for Q2, which could net back well below the published range, depending on freight rates. Settlements were indicated at a rollover for 2024 Q1, though indications on actual c.fr prices ranged from the mid-$10s/t to around $30/t. Export volumes for China have been lower in recent years and have further declined this year.

Prices for sulphuric acid exports from Japan and South Korea were assessed between -$15/t to $25/t f.o.b. for spot sales, with contracts from -$15/t to $20/t. Market sentiment remained firm despite limited spot business for cargoes of 20,000 tonnes or less given the current high freight rates. Tightness in the market persists amid strengthening markets in key import regions like India, China and Indonesia. Export prices had been under pressure from high freight rates and weakening import demand from some key import destinations, partly due to increasing domestic output in these markets, which is likely to intensify in H_2. The price range is higher than the March 2023 low of -$15/t to $0/t, which represented the lowest average since October 2020, but prices are down from a mid-point of $98/t f.o.b. in June 2022, with the upper end of the range down from the $45/t f.o.b. of October 2023. Some traders have doubted whether prices in the $20s/t f.o.b. were achievable on spot business amid scarce supply in the prompt market. Sellers are well committed for prompt availability, while regional import prices have firmed slightly. Delivered prices in key import markets, such as India and Southeast Asia, indicate netbacks no higher than the upper $10s/t f.o.b. despite some increases in those markets' c.fr levels.

Spot prices for sulphuric acid sales into Chile moved higher to $150–155 /t c.fr, as rising freight rates continued to boost prices. Given the export prices from China are around $30-35 /t f.o.b., coupled with transportation and other costs, prices in Chile are likely above the $150/t c.fr mark. Ocean swells delayed deliveries to Chile earlier this year, limiting spot demand and activity. The large line-up of deliveries for Mejillones recently eased, with tank capacity also starting to clear. Most sources expect relatively firm spot demand in the second half of the year, though some buyers argued they were comfortable for now after forward-buying volumes in the $120s/t c.fr. Chile's sulphuric acid imports from January through May 2024 were down 8% year on year at 1.46 million tonnes, according to data via Global Trade Tracker (GTT). China once again overtook Peru as the lead source of acid, with the former supplying 490,707 tonnes over the five months (up 163% year on year) while the latter supplied 451,620 tonnes (down 24%). Imports from South Korea increased 8% to 206,809 tonnes, while the volume from Japan was up 65% at 183,482 tonnes. Imports from European origins declined amid reduced arbitrage opportunities and the return of Moroccan demand for European acid supply. Chile's annual acid imports for 2023 were up 2% year on year at 3.78 million t/a, representing the highest annual acid imports to Chile on record.

Contracts for supply of sulphuric acid in Europe in the third quarter of 2024 are expected to settle at price increases from Q2. It is suggested that smelters were achieving increases of around €20, with sulphur burners arguing for climbs of €50 or more. Spot prices for sulphuric acid exports from northwest Europe were unchanged at $70–80 /t f.o.b. in May and June, with limited buying interest. Low availability of supply in the spot market has supported prices and most industry participants see little chance of price declines in the short term, but this has resulted in a lack of fresh f.o.b. spot sales. Most major European producers are well-committed, and a strong maintenance schedule is limiting availability, especially in the current quarter. There are further smelter maintenances planned for Q3, though the acid output loss is lighter than for Q2. The price range for contracts for Q2 was published at €120-140/t c.fr NW Europe, up from Q1's €110-130/t c.fr NW Europe, which was unchanged from 2023 Q4, though there were some falls on earlier Q1 settlements.

Firm sentiment is partly the result of tight molten sulphur availability in Europe. Some consumers in Europe have had to seek additional acid cargoes to compensate for a lack of sulphur, while sulphur-based acid producers are facing higher raw materials costs and limited supply. Strong international demand, particularly from North Africa, has increased spot f.o.b. prices from Europe in recent months. In addition, a strong maintenance slate in Europe tightened availability for Q2 in particular. Notably, Aurubis had a two-month maintenance planned at its Hamburg smelter through May and June. The smelter has acid capacity of around 1.3 million t/a.

Price Indications

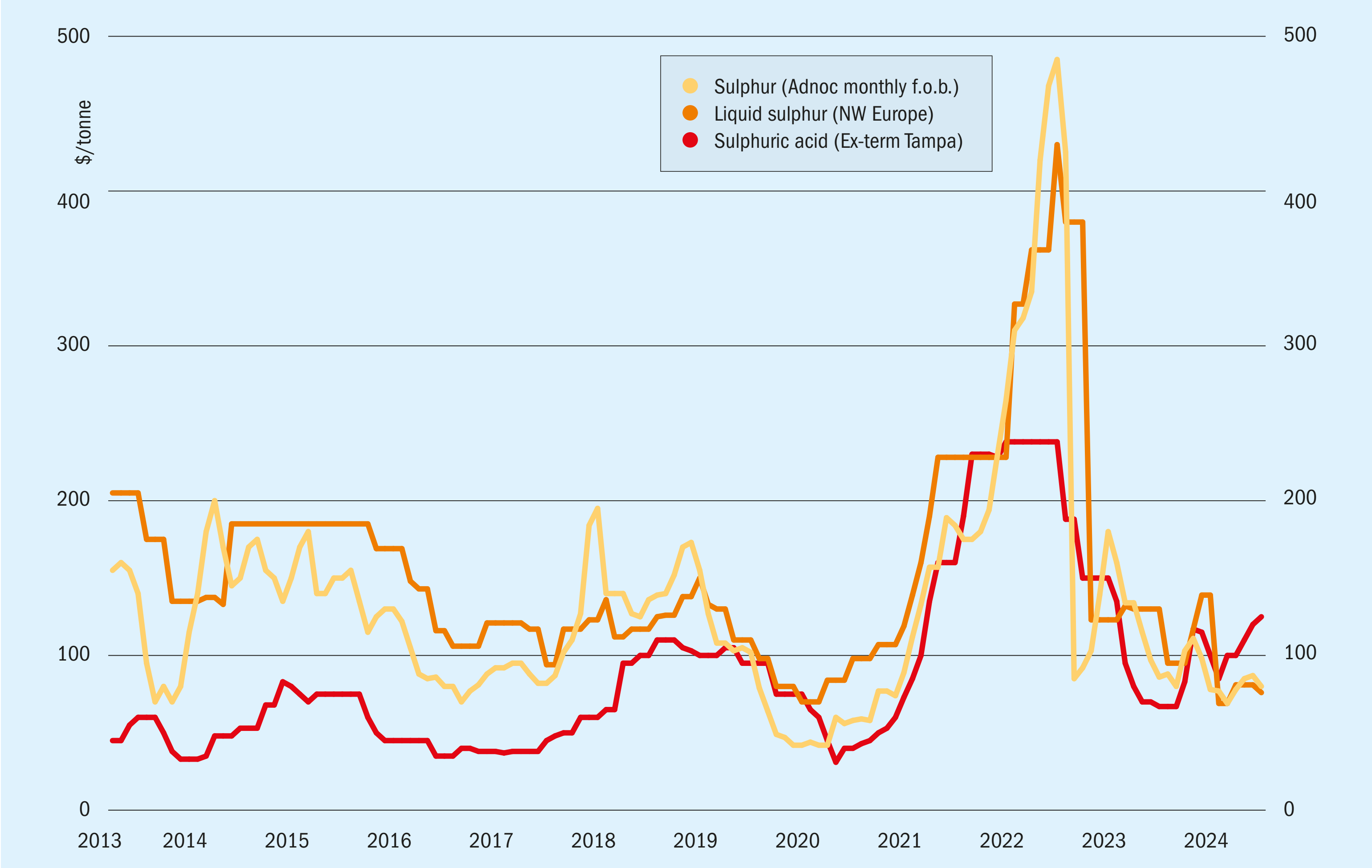
Table 1: **Recent sulphur prices, major markets**

Cash equivalent	February	March	April	May	June
Sulphur, bulk ($/t)					
Adnoc monthly contract	69	78	85	87	80
China c.fr spot	97	105	110	103	103
Liquid sulphur ($/t)					
Tampa f.o.b. contract	69	81	81	81	76
NW Europe c.fr	139	138	158	158	158
Sulphuric acid ($/t)					
US Gulf spot	100	100	110	120	125

Source: various

Market Outlook

Historical price trends $/tonne



Source: BCInsight

SULPHUR

- Sulphur prices are expected to recover from declines in May and June and continue climbing over the coming months, though good availability will limit upside.
- Port inventories in China have declined to their lowest volume this year, but remain higher than the average for 2022-23. Recent firming in domestic phosphate markets should add some support. Affordability of sulphur relative to phosphates is good, especially with DAP and MAP prices climbing, though some downstream production is still relatively weak, limiting appetite for raw material sulphur.
- Sulphur demand in Indonesia for nickel is set to increase further following a big jump in imports since 2022, limiting possible downside to global spot prices. Still, some of this demand may be met with increased domestic smelter acid output.
- On the supply side, Kazakhstan's Kashagan oilfield has faced government pressure to reduce its sulphur stocks, and crushed lump supply from the site adding to market length, though lower stock levels should ease this pressure later in the year and sales of additional volumes from stock are expected to slow.
- Overall, the recent growth in sulphur production, in addition to producer stock drawdown and high China inventories, is expected to limit upwards potential for prices in the short term and keep sulphur prices low relative to phosphates. Still, good affordability continues to support raw materials purchasing and leaves room for further price increases, especially if downstream production picks up further and sulphur stock drawdown slows as expected.

SULPHURIC ACID

- Sulphuric acid prices are expected to remain relatively firm before undergoing slight declines in Q4, but prices may be pushed down further if demand is weaker than expected.
- Smelters in Japan and South Korea are facing reduced sales options this year. China, the key source of marginal seaborne acid supply, requires higher acid prices to draw out more volume, as domestic sales offer favourable pricing.
- India's import demand is under pressure as sulphur offers a more affordable raw material option. In addition, buyers have recently added sulphur burner capacity, limiting merchant acid requirements, with additional domestic smelter acid production expected during the forecast from Adani's recently commissioned large smelter likely to cut acid import demand further.
- Indonesia imports increased steeply in 2023, but import demand there is also likely to decline as domestic production increases from both integrated sulphur burners and new smelting capacity.
- Improving availability of smelter acid and sulphur in the US Gulf has been limiting merchant acid import requirements. Sulphur availability in the region is increasing at the moment, and prices there still suggest much lower levels on acid, though strong fertilizer markets are supporting acid prices.

Sulphur Industry News

SAUDI ARABIA

Aramco sale nets $12 billion

Saudi Aramco has sold another tranche of 1.54 billion shares, amounting to 0.64% of the company's total ownership. The sale, at 27-29 riyals per share, was oversubscribed by a factor of five, making it more popular than the previous IPO, in 2019, which sold 1.5% of the company's shares for a total of $29.4 billion. Foreign take up of shares was also higher this time, with more than half of sales to foreign investors, compared to 23% for the 2019 sale. However, it remains relatively small in scale compared to Saudi Arabia's ambitions as part of its Vision 2030 plan to encourage more foreign direct investment and wean the country off its dependence on oil. Aramco is the world's largest oil company in terms of both daily crude production and market cap, and remains 82% in the hands of the government and 16% held via the country's sovereign wealth fund, the Public Investment Fund (PIF).

The sale is also small compared to the size of dividend payments that the company has made in order to keep its share price high. Saudi Arabia's public finances remain constrained by OPEC+ production caps – Aramco produced 10.6 million bbl/d in 2023, but this is currently down to around 9 million bbl/d, with production running at only around 75% of capacity. Non-oil revenues came to 50% of GDP in 2023 but oil still represents 75% of government income, and even at $77/bbl it is not covering government spending.

CHINA

Sustainable aviation fuel project for China

Topsoe has been selected by Guangxi Free Trade Zone Hongkun Biomass Fuel Co., Ltd. to deliver its *HydroFlex*™ technology for the production of sustainable aviation fuel (SAF) and renewable diesel.

Based on Topsoe technology, 300,000 t/a of feedstock will be processed into renewable fuels.

Construction of the plant is scheduled to begin in May 2024, with SAF production expected to start in the beginning of 2026. The facility will be Topsoe's first SAF project in China.

Elena Scaltritti, Chief Commercial Officer at Topsoe, said: "We continue to expand our SAF technology offering across the world, and we are thrilled to secure our first agreement to supply SAF production technology to a partner in China. This agreement represents a key step in introducing an alternative to conventional jet fuel in this geography and contributes to our sustained efforts of supporting decarbonisation globally. We look forward to further expand our relationship with Guangxi Hongkun Biomass to achieve their decarbonisation goals."

According to the International Energy Agency's Net Zero Scenario, over 10% of fuel consumption in aviation needs to be SAF by 2030 to stay on course for net zero CO_2 emissions by 2050. In 2022, the International Air Transport Association estimated global SAF production to make up only around 0.1% to 0.15% of total jet fuel demand.

UNITED ARAB EMIRATES

NextChem contract for Hail and Ghasha

Maire Group subsidiary NextChem has been appointed as technology design integrator to develop the process design package for the hydrogen and carbon dioxide recovery unit of the Hail and Ghasha gas development project. The Hail and Ghasha project, a $8.7 billion package of which was awarded to Tecnimont by ADNOC in October 2023, is one of the most important initiatives globally to decarbonise the energy processing industry. The project aims to operate with net zero CO_2 emissions, in part thanks to the recovery units to be developed by NextChem, which will allow the capture and storage of 1.5 million t/a of CO_2.

NextChem's scope of work encompasses the process design pacakge for the raw gas compression station, the dehydration and separation unit, the CO_2 compression station and other associated facilities based on best-in-class technologies and solutions. Leveraging its decarbonisation expertise and capabilities, NextChem will also support Tecnimont in supplying certain critical equipment and developing the detailed engineering design for the hydrogen and CO_2 recovery section. The overall value of the contract is approximately $ 60 million.

Alessandro Bernini, CEO of Maire, commented: "This project proves the strength of the Group's integrated approach, and how we can support customers on a broad spectrum of decarbonisation solutions."

UNITED STATES

Hydrogen from sour gas

Thiozen, a spin-off of the Massachusetts Institute of Technology (MIT), says that it has successfully produced clean hydrogen from sour gas waste streams at a pilot unit in the Permian Basin. The demonstrator unit removed hydrogen sulphide from the sour natural gas streams while simultaneously generating zero-emission hydrogen. Thoizen partnered with Texas-based oil and gas production company ACT Operating Company for the pilot to install the technology at the gas gathering site.

Marshall Watson, President of ACT Operating Company and department Chair of Petroleum Engineering at Texas Tech University, commented: "Sour gas processing is a major cost associated with energy supply, and both removing the hydrogen sulphide and producing a new energy stream in hydrogen gas is a major step-up in our industry."

Thoizen believes the process will reduce global greenhouse gas emissions by more than 300 million metric tonnes per year. Additionally, the start-up says the technology will improve air quality and respiratory health in communities near the current hydrogen infrastructure while providing cost-sensitive firms with a path to procuring additional hydrogen. The US Permian Basin has already been identified as a potential hot spot for blue hydrogen production, given its extensive oil and gas infrastructure, large volumes of natural gas production, and significant carbon capture and storage (CCS) potential.

Piñon Midstream increases sour gas capacity

Piñon Midstream says that it has commissioned its third amine treating unit at its sour natural gas treating and carbon capture facility, the Dark Horse Treating Facility in Lea County, New Mexico. The company has also received an air permit which enables the execution of additional capital expansion projects at Dark Horse, including construction of amine trains IV, V and VI, as well as two cryogenic processing plants. The current expansion increases sour natural gas treating capacity by 50% to ~270 million scf/d. The Dark Horse Treating Facility includes a total of 1,350 gallons/minute of amine treating and two acid gas injection wells, each with depths of ~18,000 feet, permitted for 20 million scf/d of acid gas injection. Since it began operations in August 2021, Piñon says that it has reduced the environmental impact of oil and natural gas production in the Delaware Basin through the capture and permanent geologic sequestration of more than 225,000 tonnes of carbon dioxide (CO_2) and hydrogen sulphide (H_2S).

Infrastructure and expansions that are included in the newly approved air permit include three additional 900 gallons/min amine treating units, each with a capacity up to 220 million scf/d; two cryogenic processing plants with total permitted processing capacity of 460 million scf/d; three dehydrators for amine trains IV, V, and VI; a 10,000 bbl/d condensate stabiliser; and 4,400 barrels of storage capacity.

Piñon's founding partner and Chief Executive Officer, Steven Green, said: "With the recent receipt of the NSR permit, Piñon is well-positioned to significantly expand our sour gas treating and carbon capture operations within the Delaware Basin. "This important milestone underscores our mission to unlock substantial acreage across the Delaware Basin while improving the environmental impact of oil and gas production."

Certification for new analysers

AMETEK Process Instruments has received third party ATEX and IECEx Zone 1 hazardous location certifications for its recently released 993X series of analysers, encompassing the 993X and 9933. Using an integrated purge and pressurisation system, the 993X analysers can be installed in locations where an explosive atmosphere is occasionally present during normal operations. The new Zone 1 certification compliments the existing ATEX, IECEx, UKEX Zone 2 and North America Class I Division 2 approvals that are also available.

Michael Gaura, senior product manager explained, "AMETEK Process Instruments recognizes plant operators are continually focused on safety and efficiency. The 993X analysers are designed to safely and continuously measure and monitor process gas streams in challenging environments. Providing analysers with Zone 1 classification, provides operators with more options, and reduces risk."

The 993X analysers use ultraviolet spectroscopy to measure hydrogen sulphide, carbonyl sulphide and methyl mercaptan in natural gas and biomethane gas streams. They are also used to measure hydrogen sulphide, carbonyl sulphide, carbon disulphide, sulphur dioxide, and hydrogen in sulphur removal and recovery operations. The analysers have ingress protection ratings of IP66 and NEMA 4X and are proven to operate in ambient temperatures ranging from -20ºC to +60ºC.

Brimstone Group LP acquires the Brimstone Sulphur Symposium

The Brimstone Group LP, a newly established entity formed by sulphur industry professionals Angie Slavens, Elmo Nasato, and Dave Sikorski, has acquired the Brimstone Sulphur Symposium from Brimstone STS. In recent months, Mike Anderson, President of Brimstone STS, has closely collaborated with the new team to facilitate a seamless transition of the event's stewardship. Anderson remarked, "The Brimstone Sulphur Symposium has been a cornerstone in our industry, and I am confident that Angie, Elmo, and Dave, with their combined expertise, will carry forward its legacy admirably."

Historically, the Brimstone Symposium has garnered acclaim as the foremost gathering for professionals specializing in amine and sulphur recovery. This year's symposium is slated for the week of September 9th at the charming Sonnenalp Resort in Vail, Colorado.

The Brimstone Group says that its establishment underscores a steadfast commitment to preserving the symposium's 30-year heritage, while promising to uphold its status as one of the premier events in the sulphur industry. "We are honoured to shepherd the Brimstone Sulphur Symposium into its next chapter," said Angie Slavens. "Our dedication lies in honouring the event's rich legacy while addressing the evolving needs of our industry." Elmo Nasato added, "This symposium has long been a crucial forum for the exchange of knowledge and innovation in sulfur recovery. We are devoted to upholding its high standards and ensuring it remains an invaluable resource for industry professionals." Dave Sikorski commented, "The Brimstone Symposium's collaborative spirit and technical depth distinguish it from other events. We are committed to continuing to foster an environment where the latest research and best practices are shared and openly discussed."

IRAN

New sulphur plant

The Neyr Perse Company, a subsidiary of Iran's oil and gas producer MAPNA Group says that it is constructing a 400 t/d sulphur plant as part of the South Pars Phase 14 development. It follows the successful start-up of a similar MAPNA-developed unit in South Pars Phase 13. The facility will process previously flared gas, reducing environmental pollution. The sulphur recovery sections of the South Pars development were originally envisioned to be designed and built by international companies, in collaboration with the respective license holders. However, the sanctions against Iran and increasing domestic capability has led to a number of Iranian companies becoming involved in their development. The recovered sulphur will be granulated for transport and export. Neyr Perse says that it is able to produce sulphur granules that meet the stringent SUDIC standard.

Sulphuric Acid News

BRAZIL

Galvani begins phosphate expansion

Brazilian phosphate producer Galvani says that it has begun work on its major phosphate expansion in Bahia state, including a new production plant at Ceará, in partnership with Indústrias Nucleares do Brasil (INB). The company aims to reduce Brazil's northern and northeastern regions' reliance on imported fertilizers. The first phase includes $133 million of investment, including $76 million for new phosphate mining at Irecê, and $38 million for Luís Eduardo Magalhães factory, also in Bahia. This expansion will take capacity from 600,000 t/a to 1.2 million t/a by 2026. The expansion at Luís Eduardo Industrial Complex includes expansion of sulphuric acid capacity from 165,000 t/a to 250,000 t/a.

The second stage of the plan involves the project in partnership with INB. Via the Santa Quitéria consortium, the companies will explore associated phosphate and uranium reserves in a deposit in Santa Quitéria, in the state of Ceará. This phase is still awaiting permits, but could begin operating in 3Q 2027. The project foresees an installed capacity of 1 million t/a of phosphate fertilizers, equivalent to around 25% of demand in the North and Northeast regions.

Metso order for Galvani fertilizer plant

Galvani Fertilizante has awarded Metso an order to deliver a lime calcination kiln and cooler package for its fertilizer plant in Irecê, Brazil. Metso says that he total value of the order is over euro 10 million. The Irecê project is a significant step for Galvani in introducing sustainable technological innovations at its industrial plants. The new unit is expected to annually produce 350,000 t/a of phosphate concentrate and 600,000 t/a of agricultural limestone. Metso will supply a rotary kiln, a rotary cooler and ancillary equipment for the project. The kiln and the cooler system are a critical part in the process to remove limestone from the phosphate concentrate. The kiln will be the largest lime calciner Metso has ever delivered, measuring almost six meters in diameter and over 140 meters in length. Metso has installed over 200 lime calcining systems globally.

"The partnership with Metso will bring strategic benefits to Galvani, allowing gains in mineral processing at our new unit in the municipality of Irecê, in Bahia. The laying of the foundation stone for this unit, which took place in May of this year, reinforces the importance of this project for the development of the economy of the state of Bahia, in Brazil, and for the generation of jobs and income. This milestone represents our commitment to innovation and development, boosting our ability to meet the demands of the fertilizer market," says Galvani's CEO, Marcelo Silvestre.

"We are proud to partner with Galvani in this project. With Metso's vast experience in lime calcining and rotary kiln technology and Galvani's rich history and expertise in phosphate fertilizers, we're certain the project will be a landmark success for both parties," says Chris Urban, Vice President, Heat Transfer at Metso.

INDIA

Coromandel starts work on new sulphuric acid plant

In an exchange filing, Coromandel International says that it has begun project activity on its new sulphuric and phosphoric acid complex at Kakinada in Andhra Pradesh. The project is expected to be commissioned in two years' time and has an estimated cost of $120 million. Coromandel says that the proposed 650 t/d phosphoric acid facility is designed with advanced dihydrate attack-hemihydrate filtration (DA-HF) process technology and an automated DCS system which provide stable supplies of phosphoric acid for its fertiliser manufacturing by replacing more than 50% of the Kakinada plant's imported acid requirement. The expansion also includes a new 1,800 t/d sulphuric acid plant to supply phosphoric acid production and produce additional power from waste heat.

Haldia refinery completes WSA plant

The Indian Oil Company Ltd (IOCL) has announced the mechanical completion of its new wet sulphuric acid (WSA) plant at its Haldia refinery. The sulphuric acid plant, with a capacity of 325 t/d, takes hydrogen sulphide rich off-gas from the amine regeneration unit and sour water stripper, recovering at least 99.9% of the sulphur as 98.5% sulphuric acid. It forms part of an upgrade to the refinery to produce Bharat-VI quality low sulphur petroleum products. Haldia Refinery is one of two refineries of the Indian Oil Group producing lube oil base stocks at Haldia, 136 km downstream of Kolkata in the Purba Medinipur district, West Bengal, near the confluence of the Hooghly and Haldi rivers.

CANADA

Worley alliance on lithium battery materials

Nano One Materials Corp. and Worley Chemetics have entered into a strategic alliance and license agreement to jointly develop, market and license a process engineering design package for the deployment of cathode active material (CAM) production facilities with potential customers in the lithium-ion battery materials sector. Nano One is a clean technology company with patented processes for the sustainable production of lithium-ion battery cathode active materials. Through Worley Chemetics, Worley offers technology and solutions for sulfuric acid and other specialty chemicals facilities.

"This licensing agreement and global strategic alliance with Worley is another major milestone for Nano One," said Nano One CEO, Dan Blondal. "It adds to the growing confidence of our shareholders, partners, and government stakeholders. It amplifies the value of our One-Pot process and addresses a growing need for a new generation of scalable battery cathode material production technology and clean, diversified supply chains. Worley has a global network of clients, deep engineering knowledge and a track record of designing and building process facilities that can accelerate our design-once-build-many growth strategy. We have found in Worley a collaborative, insightful and visionary team that is just as passionate about changing how the world makes battery materials as we are."

Nano One brings its patented One-Pot process to the alliance as well as its innovation hub in Burnaby, British Columbia, and its LFP CAM demonstration facility in Candiac, Quebec. The One-Pot process makes cathode materials by combining the processes for precursor CAM and CAM, enabling a smaller physical footprint than incumbent processes and up to 50-60% fewer carbon emissions than other battery cathode processes, as well as using 80% less process water. It also eliminates wastewater and harmful sodium/ammonium sulphate by-products, a major disposal and permitting challenge in current cathode material production processes.

UNITED KINGDOM

CRU's new Battery Technology and Cost Service now available

The Energy Transition is driving unprecedented demand for batteries, with new chemistries emerging each year, aimed at reducing costs, improving performance, or both, staying informed is imperative to capitalise on emerging trends, navigate technological advancements effectively, manage procurement and risk and grow financially and strategically. CRU's Battery Technology and Cost Model offers unparalleled data and analysis capabilities, empowering businesses within the battery space to make strategic decisions.

It model hundreds of battery technology combinations, and allows users to benchmark battery technologies, comparing energy density and production cost over a ten-year forecast, including next-generation cells. Users can also review forecasts for key metrics, including raw material prices, over a 10-year forecast using CRU data. The service covers all key markets, including China, USA, Europe, South Korea, Japan, the UK and Canada, comparing labour rates, labour cost, electricity cost and production yield by country. Enquiries can be made to sales@crugroup.com.

SERBIA

Elixir to decarbonise phosphate production

The Elixir Group plans to install a solar power plant, a wind farm, a battery storage facility, and start using waste for the production of steam, as part of a €300 million investment plan, according to Matthias Predojević, Vice President for Corporate Development. The new investments will help push forward the decarbonisation process in Elixir Group. Elixir operates at two locations in Serbia at Elixir Prahovo and Zorka Šabac, with a capacity of 1 million t/a of mineral fertilizers and phosphoric acid. At Prahovo the firm intends to invest in a new phosphoric acid plant, using steam from non-recycled waste, and electricity from wind and solar energy production.

SAUDI ARABIA

Acid imports down 50% in Q1

Saudi Arabia imported 96,141 tonnes of sulphuric acid during January-March 2024, down 50% from the equivalent period in 2023, according to Global Trade Tracker (GTT). Imports from Japan climbed from nothing to 40,400 tonnes, while the volume from South Korea was down 38% at 25,846 tonnes. The volume from China was down 84% at 19,394 tonnes, while acid received from Taiwan, China was roughly stable at 10,501 tonnes.

Saudi phosphates producer Ma'aden first purchased spot acid in November 2020, buying a cargo from Chinese sulphur burner Two Lions via a trader. The buyer then made a range of acid purchases through 2021 and 2022. Saudi imports for January-December 2023 were up 14% year on year at 565,488 tonnes, according to GTT, while annual imports for 2022 were up 53% at 493,954 tonnes. The company typically bases its production off its own acid output, produced using Saudi sulphur from Aramco. Ma'aden enquired about acid purchases several times throughout 2020, but no deal was concluded until the November purchase.

Ma'aden to buy out Mosaic's share of phosphate JV

Saudi Arabian mining company Ma'aden has announced the acquisition of Mosaic's 25% stake in the two companies' phosphate joint venture Ma'aden Wa'ad Al Shamal Phosphate Company. Ma'aden finalised a stock purchase and subscription agreement with Mosaic. Under the terms of the agreement, Ma'aden will issue nearly 111 million new shares, worth a total of $1.49 billion, to acquire the 25% stake. The deal will increase Ma'aden's stake in Wa'ad al Shamal from 60% to 85%, and also significantly expand its phosphate production capabilities.

UNITED STATES

New alkylation complex

Next Wave Energy Partners has selected Elessent Clean Technologies to provide STRATCO® alkylation technology at the world's first stand-alone alkylation complex in Pasadena, Texas. The complex operates as an ethylene-to-alkylate facility, eliminating the need for crude oil and significantly reducing carbon intensity compared to traditional methods.

"We are immensely proud to announce our part in the launch of this groundbreaking alkylation complex. Collaborating closely with the Next Wave team over the past decade has been an honour. As we forge ahead, we eagerly anticipate further collaboration, aiding Next Wave in expanding horizons and diversifying feedstocks, all while relentlessly pushing the boundaries of industry norms," said Eli Ben-Shoshan, CEO, Elessent Clean Technologies.

Asarco to restart copper smelter

Grupo México says that its Asarco subsidiary will restart its mothballed copper smelter in the United States due to high copper prices. Asarco bought the Hayden smelter in Arizona and associated copper mines in 1999. The US currently has only two domestic copper smelters; Freeport McMoRan's Miami smelter in Arizona, and Rio Tinto's Kennecott smelter in Utah. Asarco is now said to be in negotiations with miners and staff over the restart, and has extended its air quality permit. The US produced 880,000 t/a of refined copper in 2023, according to the International Copper Study Group, although it imported 770,000 t/a and consumed more than 1.6 million t/a of refined copper.

KAZAKHSTAN

Agreement for copper smelter project

Kazakhstan has signed an agreement with China to build a new copper smelter with a capacity of 300,000 t/a of copper. The agreement was signed between KAZ Minerals Smelting LLP, China Nonferrous Metal Industry's Foreign Engineering and Construction Co., Ltd. (NFC), and NFC Kazakhstan LLP. The smelter, costed at $1.5 billion, will be built near the village of Aktogai in the Abai Region near one of the world's largest copper mines, and will supply Kazakhstan's domestic demand for copper for in the power industry and other industrial sectors. The complex will also include a new sulphuric acid plant. It is scheduled to be commissioned by the end of 2028.

EuroChem signs agreement for phosphate expansion

EuroChem has signed an agreement with China National Chemical Engineering Co. (CNCEC) for the design, construction and commissioning of a chemical complex in Janatas in Kazakhstan's Jambyl region. Combined total investment to date and planned capital expenditure will exceed

$1 billion. The project is the third phase of EuroChem's phosphate development. The first phase involved building and commissioning a phosphate mine. As part of Phase II, a contract has been signed and the company has started construction of a sulphuric acid facility to be commissioned in 2026. Following the completion of Phase III, in 2027, EuroChem will commission a chemical complex with a total annual output in excess of 1 million t/a of mineral fertilizers and associated industrial products, with distribution in Kazakhstan and Central Asia, as well as China, Russia and Europe. According to EuroChem, the new plant's technology will enable it to avoid phosphogypsum waste, replacing it with more eco-friendly synthetic gypsum and calcium chloride – by-products used in construction materials and as reagents for the road construction, coal and hydrocarbon industries.

MOROCCO

US raises duty on Moroccan phosphates

The US Department of Commerce (DoC) has announced an increase on import duties for fertilizers from Morocco. The move relates to a request from US fertilizer producer Mosaic received in May 2023. In June last year the DoC published a notice of initiation of an administrative review of the countervailing duty (CVD) order on phosphate fertilizers from Morocco, and it has twice extended the deadline for the preliminary results of this review, which was finally completed in April 2024. The determination is backdated to imports from January-December 2022, and increases import duties on Moroccan fertilizers from 2.12% to 14.21%, while lowering duties on Russian phosphate fertilizers to 18.83% from 28.5%.

INDIA

HURL concludes SSP distribution agreement

Hindustan Urvarak & Rasayan Limited (HURL) has entered into an agreement with fertilizer producers in India for distribution of single superphosphate (SSP). The agreement covers the supply of 500,000 tonnes of SSP for distribution across 13 Indian states in 2024-2025. The product will be supplied by companies including Agro Phos India Ltd, Khaitan Chemicals & Fertilizers Ltd, and Rama Phosphates Ltd.

Aramco's Jazan refinery, Saudi Arabia

PHOTO: SAUDI ARAMCO

CHILE

Copper output down at Codelco

Copper production at Chilean miner Codelco was reportedly 484,500 tonnes in the first five months of the year, 6.1% under the company's target. May's output of 103,100 tonnes was 8.6% below the goal, according to Reuters, while April production of 95,100 tonnes was the first time a month's output was below 100,000 tonnes in at least 18 years. The state-owned company lost production when it suspended activity at Radomiro Tomic to enable an inspection following a fatal accident in March. A workers' strike at the mine added to the company's woes. As lower ore grades across all operations is the underlying reason for reduced output, Codelco has embarked on a multi-billion dollar investment programme to return production to the historic level of around 1.7 million t/a.

FINLAND

Metso technology for quenching of off-gas

Metso is reintroducing the OtoVentTM off-gas treatment technology for the quenching of various types of off-gases in non-ferrous and ferrous metallurgical processes and in oil, gas and chemical plants. OtoVent technology is used, for example, at the most modern copper smelters. It incorporates high quenching and pre-dedusting capability, and the design ensures lower maintenance effort. Metso says that its compact size also makes it suitable for both greenfield and brownfield installations and it is an exceptional replacement for existing quenchers

SAUDI ARABIA

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People

The International Fertilizer Association (IFA) elected seven new representatives to its Board of Directors at its Annual General Meeting, held in Singapore on 22 May. The AGM took place on the final day of the IFA Annual Conference 2024. The seven new Board Directors elected by the membership are: **Bruce Bodine**, Mosaic; **Soufiyane El Kassi**, OCP Nutricrops; **Xiaofeng Hou**, China BlueChemical; **Dmitry Konyaev**, Uralchem JSC; **Jahangir Piracha**, Fauji Fertilizer Company Ltd; **Edward Weiner**, Trammo, Inc.; and **Kelvin Wickham**, Ballance Agri-Nutrients.

Alzbeta Klein, CEO and Director General, IFA, said: "I warmly welcome each of our new members to the IFA Board of Directors. I am looking forward to working with them all in support of IFA's mission to help feed the world sustainably."

IFA welcomed 34 new members to the Association – five Ordinary Members, 24 Associate Members, two Affiliate Members and three Correspondent Members, and awarded its 2024 Green Leaf Award for outstanding safety, health, and environmental practices to Engro Fertilizers in Pakistan for nitrogen production, and to IMACID (a joint venture of OCP, CFCL Group, and TATA Chemicals) in Morocco for phosphate/potash production. Applicants for the Green Leaf Award undergo an extensive evaluation of performance indicators by an independent panel of experts. IFA runs the award every two years and received a record 47 eligible applications from 27 member companies in 2024.

IFA noted that Engro Fertilizers' application exemplifies a comprehensive approach to safety, health, and environmental (SHE) management in its fertilizer manufacturing division. Through robust SHE programs and strategic initiatives like the ECO-GREEN project (a 60-day project aimed at enhancing plant energy efficiency, including the inspection and repair of 400 equipment pieces and installation of low NOx burners) Engro Fertilizers demonstrates a commitment to reducing emissions and promoting sustainability.

Brazilian state oil company Petrobras has appointed **Magda Chambriard** as its new Chief Executive Officer. Chambriard has spent four decades in the industry and is a former head of oil and gas regulator ANP. She was chosen by president Luiz Inacio Lula da Silva to replace former CEO Jean Paul Prates after he was dismissed on May 14th, the day after the publication of results showing a 38% drop in profits year on year for Petrobras. The results and turbulence at the top of the company led to a sharp drop in Petrobras share price. However, Brazilian Mines and Energy Minister Alexandre Silveira has sought to allay fears about political interference, stating that Chambriard would execute the firm's existing $102 billion investment plan for the 2024-2028 period.

TotalEnergies SE has reappointed **Patrick Pouyanné** as Chairman and CEO and confirmed **Jacques Aschenbroich** as Lead Independent Director at a combined shareholders meering on May 24th. The shareholders adopted all resolutions supported by the board of directors, including approval of the 2023 financial statements and payment of an ordinary dividend of €3.01 per share, and renewal of the three-year terms as directors of Patrick Pouyanné, Jacques Aschenbroich and Glenn Hubbard, as well as appointing Marie-Ange Debon as director for a three year term.

Closing the shareholders' meeting, Patrick Pouyanné declared: "I would like to thank our Shareholders for their support on the resolutions approved by the Board of Directors, and in particular to the renewal of my term of office as Director and that of Jacques Aschenbroich, Lead Independent Director, as well as to the report on the transition strategy implemented by the Company".

MBAC Fertilizer Corp, which last year began production of phosphate fertilizer at its Itafos facility in central Brazil, has appointed **Cristiano Melcher** as president and CEO. The previous CEO, Antenor Silva, will step down from that position and remain a director, MBAC. Melcher was previously CEO of Fosbrasil, a South American producer of purified phosphoric acid, and before that executive director of Copebras, a Brazilian phosphate producer owned by Anglo American PLC. MBAC's previous chief operating officer, Roberto Busato Belger, left the company in November.

Calendar 2024

SEPTEMBER

1-5
Sulphuric Acid Plants Round Table, PUERTO VARAS, Chile
Contact: Hotlec ltda, San Felipe, Chile
Tel: +56 34 251 5557
Web: https://mesaredondachile.com/en/holtec-round-table-2024-welcome

9-13
31st Annual Brimstone Sulphur Symposium, VAIL, Colorado, USA
Contact: Mike Anderson, Brimstone STS,
Tel: +1 909 597 3249
Email: mike.anderson@brimstone-sts.com

9-13
Sulphur Experts' Amine Treating and Sulphur Recovery Technical Training Course, KANANASKIS, Alberta, Canada
Contact: Jamielynn Russell, Sulphur Experts
Tel: +1 403 215 8400
Email: Jamielynn.Russell@SulphurExperts.com
Web: SulphurExperts.com/Courses

11-12
Oil Sands Conference & Trade Show, CALGARY, Alberta, Canada
Contact: Bruce Carew, EventWorx
Tel: +1 403 971 3227
Email: marketing@eventworx.ca

16-20
Sulphur Experts' Sulphur Recovery Technical Training Course, KANANASKIS, Alberta, Canada
(Contact details as before)

30-Oct 4
Sulphur Experts' Amine Treating and Sour Water Stripping Technical Training Course, NOORDWIJK, Netherlands *(Contact as before)*

OCTOBER

8-9
TiO2 2024, VIENNA, Austria
Contact: Smithers
Tel: +44 (0) 1372 802000
Email: eventseu@smithers.com
Web: https://www.smithers.com/services/events/2024-conferences/tio2-europe-2024

15-17
AFPM Annual Summit, NEW ORLEANS, United States
Contact: American Federation of Petroleum Manufacturers
Web: https://summit.afpm.org/about-summit

NOVEMBER

4-6
CRU Sulphur & Sulphuric Acid Conference 2023, BARCELONA, Spain
Contact: CRU Events
Tel: +44 (0) 20 7903 2444
Email: conferences@crugroup.com

11-14
European Refining Technology Conference, LISBON, Portugal
Contact: World Refining Association
Tel: +44 7384 8056
Web: worldrefiningassociation.com/event-events/ertc

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

Phosphate markets

Intermittent supply from China due to export restrictions and US duty changes have kept markets guessing over the past couple of years, and there is no sign of that changing.

PHOTO: MA'ADEN

The Ma'aden 3 phosphate plant under construction

Phosphate prices started 2023 still at elevated levels after the price spikes seen in 2021-22 (Figure 1). They slid towards the end of the second quarter, albeit still at levels higher than before the run-up in prices that began in 2020, but then turned sharply back upwards again towards the end of 2023 and into 2024. The second quarter of 2024 has seen prices soften again as Chinese export restrictions appear to have moved the market into an annual cycle.

Key events of 2023

Last year saw prices of phosphate fertilizers soften in most key global markets at the start of the year. Demand was limited in India, the US, and Europe. Even so, steady sales were recorded from China, despite the reported lack of Chinese DAP/MAP availability under Q1 export quotas set by the government. These Chinese export sales added to the downward price pressures linked to weak demand. Brazil was the one market which bucked this general early 2023 trend, with the affordability of MAP relative to crop prices favourable enough to encourage buying interest.

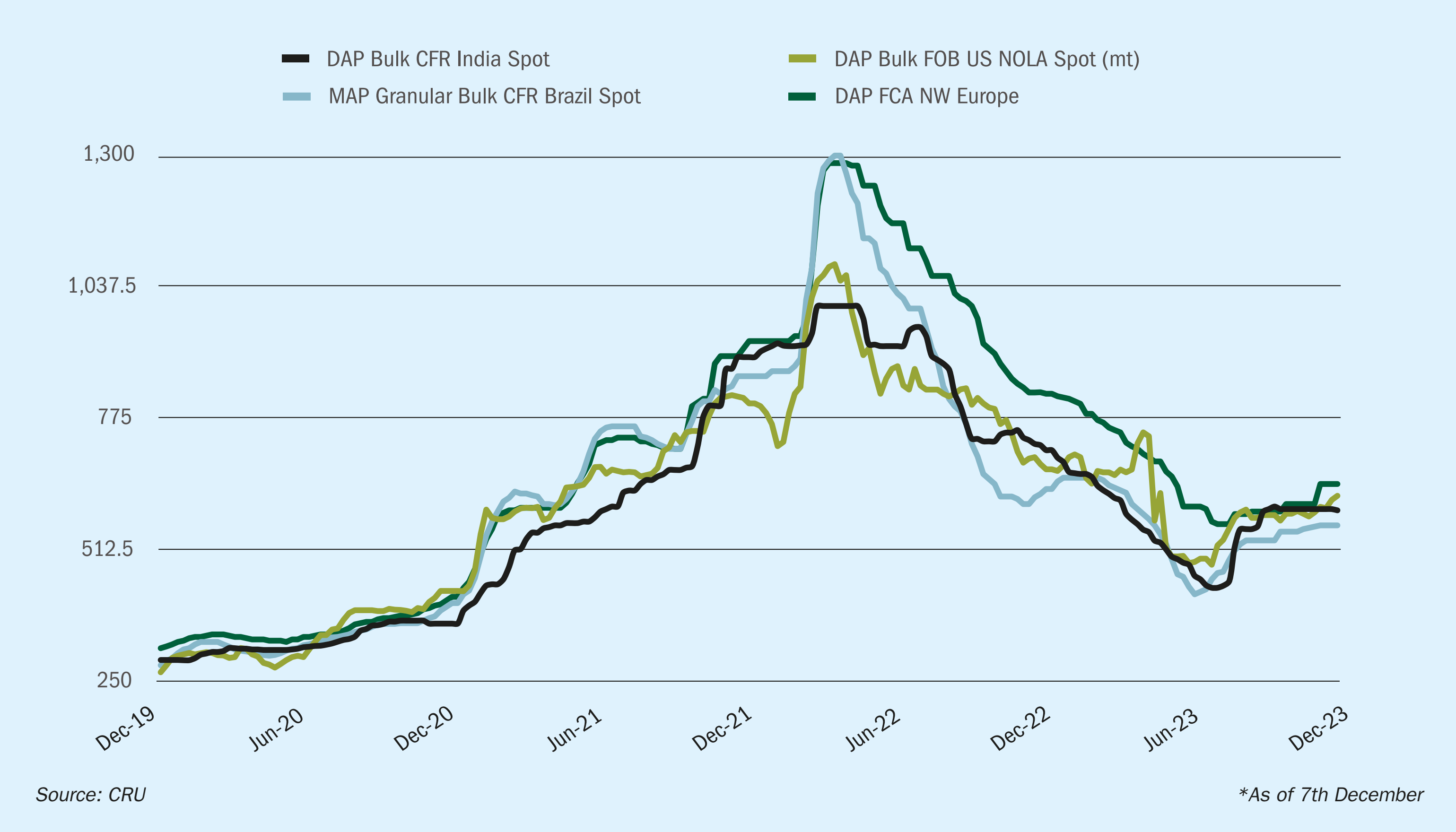
DAP/MAP demand remained weak over most first quarter, which more than compensated for low supply from China and Morocco. OCP was operating its granular fertilizer capacity at just 50%, according to CRU estimates, and prices were pushed lower in early Q2 by a combination of reduced raw-material costs, rising stocks, limited demand, and growing expectations of easing export quotas in China.

In the US, however, the Easter period saw a phosphate price surge on the back of spring demand. This resulted in the New Orleans (NOLA) DAP price becoming the world's highest benchmark, reaching $620-700/st f.o.b. ($681-770/t) during this period. But the US price surge eventually came to a halt when India's Q2 phosphoric acid contract price was agreed at $970/t c.fr in April, down $80/t from Q1. This prompted a memorable collapse in NOLA DAP prices in early May.

It was around this time that China's government acted to ease export restrictions by cutting inspection times for DAP/MAP exports to a maximum of 10 days. The move almost immediately resulted in greater overseas market availability at more aggressive prices. Consequently, China's DAP export prices started slipping below $500/t f.o.b. in mid-to-late May, while domestic prices also tumbled.

This fall continued throughout June, but although India's DAP prices remained

Fig 1: **Selected DAP/MAP benchmarks, December 2020 – December 2022***



under downwards pressure at the start of Q3, other markets did finally reach their floor around then. Brazil's MAP prices started to firm on the back of improved demand, and tight supply in the US supported a strong rebound in DAP/MAP prices. By August, a drop in DAP export supply from China prompted a price surge in India, with price rises spreading the bullish sentiment to other markets.

Prices climbed higher across most key global benchmarks in September as global DAP/MAP supply tightened. Availability from China was scaled back and plant maintenance restricted Russian availability in September-October. Production issues were also reported in the US and in Saudi Arabia. In addition, monthly volumes from OCP were judged to be below production capacity, despite an apparent increase in sales. Steady demand from India also tightened supply.

India once again took centre stage in late October as the government finally announced a cut to the nutrient-based subsidy (NBS) for fertilizers in the Rabi season. The 31% drop in the NBS for DAP from 1st October was widely expected in the market and therefore did not impact DAP prices. At the same time, however, China's National Development and Reform Commission (NDRC) tightened DAP/MAP export restrictions by suspending export inspections. The US Department of Commerce (DoC) also slashed the countervailing duty rate on imports from Morocco's OCP from 19.97% to just 2.12% at the start of November, while at the same time tripling the CVD on imports from Russia's PhosAgro. This was initially expected to lead to more Moroccan exports to the US, but earlier this year the DoC reversed its earlier decision and moved CVD rates for Morocco back to 14%, and the increase in Morocco imports to the US is unlikely to arise now.

Supply

China remains the key question on the supply side. Export restrictions were tight for the first quarter of 2024, and there were virtually no exports from January-March, when restrictions were eased again. They are expected to remain at their relatively lax state until October, when they will likely be tightened again; restrictions in 2024 and future years are expected to continue on this pattern, with almost no exports in Q1 and Q4, before loosening in Q2 and Q3, and very high availability. The quota allocation for Chinese phosphate exports has been set at 6.6 million tonnes of DAP and MAP combined for 2024. This is down from 6.9 million t/a in 2023, and China has probably passed its peak of phosphate exports as the government continues to prioritise domestic food security and fertilizer availability. Domestic consumption has also been on a secular decline, owing to a historic overapplication of fertilizers. Overall Chinese DAP/MAP/TSP exports are expected to stabilise at a total figure of 7.5 million t/a for the next few years.

Elsewhere, in Morocco OCP is expected to bring more availability to the market in 2024 compared to 2023, but their strategy remains uncertain. OCP maintained a volume control strategy in 2023 as prices soared, but increased exports in Q1 2024, when exports of finished phosphates were 1.9 million tonnes, near record levels and an increase of 30% year on year. TSP availability in particular has been better, with 2024 likely to see 1.7 million t/a of exports, largely to Bangladesh and Brazil, a 63% year on year increase. OCP continues to use its flexible production lines to slowly shift to more TSP production, as it avoids using imported ammonia, which has been expensive over the past few years. Total phosphate exports could reach 9.3 million t/a in 2024, up 5.6% on 2023. However, given the reversal in

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

US countervailing duty, OCP is unlikely to return to the US market. And as ammonia prices fall, OCP may switch back towards MAP/DAP production.

In the US, Mosaic's MAP production continues to decline, as the company continues to shift production from DAP/MAP to its line of lower grade Microessentials (between 33-40% P205 content), possibly due to lower rock quality in Florida. DAP+MAP production has fallen from an average of 4.8 million t/a from 2018-2021 to an average of 3.5 million t/a. Production was also impacted in Q4 2023 by sulphuric acid production issues.

Strong export growth from Saudi Arabia is likely, especially once the Ma'aden Phosphate Company's third plant is operational, with 1.5 million t/a of capacity in 2028 and another 1.5 million t/a by the end of the decade.

Russian exports are likely to fall however in spite of some marginal increases in production. Domestic demand is growing rapidly. Although there are some export restrictions, the quotas have been set above typical export levels, and are not expected to have a significant impact. But a shortage of Russian phosphate rock means that operations at Lifosa in Lithiania are unlikely to resume.

Overall global phosphate production is expected to be down 2% and trade down 8%, mostly due to fewer Chinese exports.

New capacity

OCP and Ma'aden make the bulk of upcoming capacity additions. Ma'aden is expected to commission its Phosphate III mega-project by 2027-28. OCP has ambitious expansion plans, with an additional granulation line next year and two gigantic TSP production centres in the years after that. OCP has finished the first two of its three 1 million t/a expansions at Jorf Lasfar, with the third expected in 2025. It also has plans for a large expansion in TSP production at Jorf Lasfar, aiming to bring 1 million t/a of capacity on-stream by 2025. There are also plans for a TSP production hub in its central-Safi axis. The Mzinda Phosphate Hub will use rock from Gantour and from the new Meskala mine, and will bring another 2 million t/a of TSP capacity online by about 2028. There are also two more projects which remain more uncertain, including another 2 million t/a of unspecified fertilizers in the Safi axis, and a new facility in Boucrâa.

Demand

Agricultural demand has been good, with record global production of corn and soybean expected in the 2023/24 growing year. However, falling crop prices have stabilised during Q2 with weather in Brazil causing supply concerns. Nevertheless, grains and oilseeds supply is expected to improve considerably this year which will cap any further rises.

The US is likely to plant 92 million acres of corn in 2024/25, down nearly 3 million acres from 2023, but soy area is conversely likely to expand by more than 4 million acres to 88 million acres – the highest area since 2018, boosted by more favourable pricing dynamics and a US EPA mandate for the production of 3.04 billion gallons of renewable diesel fuel this year. Brazil's soybean planted area is set to rise by about 2.6% this year, but despite China importing corn in bulk quantities from Brazil, the outlook for corn area in Brazil is less optimistic, with an 8.5% year on year drop expected.

In the medium term, fertilizer demand is likely to keep growing, but demand may not return to pre-2022 levels until late 2025 because of a tighter global supply, as China continues export restrictions and OCP appears to scale back exports for longer than expected. In practice, this means that theoretical agricultural demand is outpacing real fertilizer demand, in turn resulting in a necessity for more efficient applications. This is most prominent in China, which has a growing agricultural demand but a falling fertilizer demand. Counterbalancing this is better affordability and increasing crop areas in India, the US and Brazil. US phosphate demand is expected to be stagnant over the next few years, with an increasing reliance on lower-spec products like micro essentials. Indian demand has been slightly inflated by a low Maximum Retail Price in the build-up to the 2024 elections and is likely to slow its growth into next year. Import demand is very dependent on pricing and availability from China, but there is also growing SSP production in the country. India continues to be a major importer of merchant-grade phosphoric acid – it accounts for around half of global imports.

Elsewhere in South Asia, after two years of very low phosphate application due to floods and financial difficulties, Pakistan looks set to increase its import volumes into 2024, after largely depleting its stocks last year.

Brazilian stocks are low, and the country will need to import heavily from May to be able to fulfil demand. This appears to be possible with better Chinese supply and falling prices, and affordability is improving. Some relief will be provided by the commissioning of the Serra do Salitre plant, but imports will still need to dramatically ramp up in coming months to meet domestic demand.

Pricing

A stalemate of supply and demand finally broke in 2024 Q2, as DAP/MAP prices fell following increased supply availability from China. This coincided with the peak importing periods in Brazil and India, allowing for better supply availability until restrictions return in October. The floor price is likely to be reached in India by August, just breaking the breakeven prices of $485/t. At this point, the pressure to build stocks in preparation for China's export restrictions and peak Rabi demand will cause prices to rebound.

Prices of inputs are softening, meanwhile. Sulphur prices are at a notable low, but with overall upwards pressure. However, it is low enough that it is not a significant cost factor into finish product prices.

Ammonia saw a rally in late 2023 but is already falling again. Phosphate rock prices are softening as OCP begins to significantly increase exports from the end of 2023. Freight rates increased dematically because of drought in the Panama Canal, but have since fallen significantly, as less congestion has led to lower auction prices and shorter waiting times, making transit once again a more viable option compared to diverting around South America. Bulk freight rates in the Red Sea have increased due to the attacks by Houthi rebels in Yemen on shipping, but sharp rate rises have been more present in container freight markets. In any event, freight rates only make a small portion of phosphate c.fr prices and will not be significantly impacted by the conflict in the Red Sea.

Overall, the phosphate cost floor is expected to remain reasonably flat. As input costs continue to fall, and DAP/MAP prices stay high, the marginal tonne will just meet the DAP f.o.b. Morocco prices, before both plateau over the coming years. ■

PHOTO: ALAMY

New Asian refining capacity

The refining industry continues to pivot towards Asia, with knock-on effects for sulphur output.

The Hengli Petrochemical refinery at Dalian, China

The refining industry, the source of half of the world's elemental sulphur, continues to grapple with a variety of changes. In the OECD countries of Europe, North America and East Asia, plateauing or falling demand due to improved fuel efficiency of vehicles and the continuing spread of battery and hybrid powered cars are reducing demand, while the sanctions following the Ukrainian invasion has radically disrupted flows of both crude and refined products; Russia was not only a major supplier of crude oil to Europe but also diesel. At the same time, Asia continues to build large integrated refineries to deal with rising fuel demand from increasing vehicle ownership and use and the replacement of imported refined products with domestically produced ones.

Overall oil demand continues to rise, but the rate of increase is slowing rapidly after the rebound following the disruption of the covid pandemic, and are forecast to plateau as the world reaches the peak of oil demand around the end of the decade. In its May 2024 Oil Market Outlook, the International Energy Agency forecast that global oil demand is set to rise by 1.1 million bbl/d in 2024, and 1.2 million bbl/d in 2025. Supply rises only by 580,000 bbl/d. with non-OPEC output increases of 1.4 million bbl/d balanced partially by 840,000 bbl/d of OPEC+ output cuts. Oil output continues to rise in the US, Guyana, Canada and Brazil. Prices have held relatively steady over the past year. Benchmark oil prices corrected sharply lower over the course of April and early May, as concerns over the health of the global economy and oil demand fuelled a sell-off. Reports of progress towards a truce in Gaza also weighed on oil prices, although geopolitical tensions remain high. Brent crude futures traded at around $83/bbl, down somewhat in spite of signs of tightness in the crude oil market.

Refining

Global refinery margins are currently at around two year lows, particularly in Europe, but also the US and Singapore. However, annual growth in refinery activity is forecast to accelerate from just above zero in 1Q24 to 500,000 bbl/d in Q2 and to 1.8 million bbl/d b/d in the second half of 2024. Refinery throughputs passed a low point for the year at 81.4 million bbl/d in February, with crude processing increasing to reach a summer peak of around 85.6 million bbl/d in August. Much of the increase in processing will be a recovery in refining rates in the US and Europe, although European refiners face longer term problems including declining regional demand, the loss of access to Russian crude, less flexible operations and lack of petrochemical integration, as well as high costs for utilities.

Most of the increase in refining activity is coming from outside the OECD. The Middle East is forecast to increase crude runs by 650,000 bbl/d this year, the largest gain of any single region, driven mainly by the continuing ramp up of operations at the 650,000 bbl/d Al Zour refinery in Kuwait towards full production. Saudi Arabian output is also up around 300,000 bbl/d year on year due to the completion of planned maintenance work.

Elsewhere, India and China have benefited from heavily discounted Russian crude supplies, leading to an increase in refinery activity of around 100,000 bbl/d in 1Q 2024. Overall, new refining capacity in Africa, the Middle East and Asia will underpin annual gains of 1.2 million bbl/d.

China

China has been the major driver of new refining capacity over the past decade. China's annual oil refining capacity rose to 936 million t/a (18.7 million bbl/d) in 2023, making it the largest refining sector in the world in terms of capacity, according to official figures. China's oil consumption was about 756 million t/a (15.1 million bbl/d) last year, and its crude oil processing was 738 million t/a (14.8 million bbl/d), both reaching record highs. However, this was the tail end of the years of record breaking growth in the Chinese economy. As the rate of GDP growth has slowed to 6%, and possibly 4-5% in 2024-25, combined with the rapid domestic uptake of oil-substituting technologies such as electric vehicles (EVs) and high-speed rail China's share of global oil demand growth is likely to fall to around one third. As a result, refining capacity growth has slowed, as seen in Table 1.

Table 1: **Chinese refinery capacity, million bbl/d**

1980	1.8
1990	2.9
2000	5.4
2005	7.2
2010	12.3
2015	15.0
2020	16.7
2023	18.5

Source: XINHUA

China's refining capacity is expected to rise by 2.7% this year to 961 million t/a (19.2 million bbl/d), but this continues to run significantly in excess of demand. This means that China needs to maintain large export volumes in order to balance the domestic market, and overcapacity continues to dog the industry. New refining capacity includes a 400,000 bbl/d refinery in Shandong province operated by Yulong Petrochemical, the start-up of which has now been pushed back to 2025, and 200,000 bbl/d at Sinopec's Zhenhai Petrochemical and Refining, where a new ethylene plant is scheduled to be operational by the end of 2024. Production also continues to ramp up at Guangdong Petrochemical, which started up last year. Saudi Aramco is investing in a new 200,000 bbl/d refinery at Liaoning.

There are also closures, however. China has set a minimum size for new oil refineries of 10 million t/a (200,000 bbl/d), and will ban small crude processors that claim to be chemicals or bitumen producers under a plan by the National Development and Reform Commission (NDRC) to rationalise Chinese refining capacity and improve efficiency. The plan caps total refining capacity at 1 billion t/a by 2025, and is also likely to lead to much tighter scrutiny of plans for new refineries, with an emphasis on brownfield expansions at existing sites operated by major players such as Sinopec, CNPC (PetroChina) and CNOOC, and integration into petrochemicals production. PetroChina closed a 120,000 bbl/d distillation unit at Dalian in October 2023. Overall around 55% of refineries are forecast to be over the 200,000 bbl/d cap by 2025, and the NDRC continues to try and close China's large collection of small, so-called 'teapot' refineries of 40,000 bbl/d and under. China has about 34 refineries of 200,000 bbl/d or more, with combined processing capacity of 480 million t/a (9.6 million bbl/d), according to Sinopec.

Chinese refinery throughput is expected to reach 752 million t/a (15.1 million bbl/d) this year, up 1.8% year on year, and equivalent to a capacity utilisation rate of 78%. In addition to the expansions already mentioned, a further five refineries with a total refining capacity of 1.2 million bbl/d are due to come on stream by 2030, including the 300,000 bbl/d Huajin Aramco Petrochemical Company in Liaoning province in the northeast, and the 320,000 bbl/d Sinopec Gulei refinery. The Caofeidian V refinery, with a capacity of 400,000 bbl/d is due to start up in 2029. Operated by Hebei Xinhua Petrochemical Co, it is a coking refinery with integrated petrochemical production.

South Asia

Outside of China, the other major growth area for new capacity is in South Asia, particularly India. India added 39 million t/a (780,000 bbl/d) of refining capacity over the past decade, but is poised to add another 57 million t/a (1.1 million bbl/d) before 2030, according to the government, most of it via expansions at existing sites. India's refining capacity reached 254 million t/a in 2023, just over 5 million bbl/d, and in the 2023 financial year Indian refineries processed 5.13 million bbl/d of crude oil. India's oil consumption is rising as its economy expands at around 7% per annum, with booming construction and manufacturing sectors. Cheap Russian oil has also helped boost margins.

At present there are 37 million t/a of refinery projects under construction/development. Indian Oil Corp.'s Panipat refinery in Haryana state is adding 200,000 bbl/d of crude distillation unit (CDU) capacity this year as part of an expansion, and Hindustan Petroleum Corp.'s new Barmer refinery in the northwestern state of Rajasthan will add 180,000 bbl/d next year. Smaller expansions are being conducted at the Visakhapatnam and Gujarat refineries, and the Barauni plant at Begusarai city in Bihar state. Other new projects include Chennai Petroleum Corporation Limited (CPCL) – a subsidiary of state oil giant the Indian Oil Corporation (IOC) – which is aiming to complete the construction of a 180,000 bbl/d refinery by the end of 2027, Nayara Energy's Vadinar Refinery expansion, which includes 515,000 bbl/d of crude distillation capacity, and IOC's Panipat expansion projects, with another 200,000 bbl/d of capacity.

Pakistan also has major plans for refinery expansions, including the 300,000 bbl/d Gwadar refinery, owned by the Pakistan State Oil Co., which is being backed by both Chinese and Saudi investment money. Pakistan Refinery Ltd is also doubling its capacity from 50,000 bbl/d to 100,000 bbl/d.

Chinese money is also flowing into Sri Lanka, where Sinopec is close to completing a feasibility study on two refinery projects. Sri Lanka currently has only one ageing 38,000 bbl/d refinery, but Sinopec is looking at the options of either a single 160,000 bbl/d refinery or two 100,000 bbl/d facilities at the port of Hambantota, which itself has been developed with Chinese money as part of the 'Belt and Road' initiative.

On top of these, there are a number of other refinery projects elsewhere in Asia. In Indonesia, Pertamina's Balikpapan refinery expansion is expected to increase capacity from 260,000 bbl/d to 360,000 bbl/d this year.

The last refining boom?

While there are a number of new refineries under construction in Asia, most industry commentators expect this to be the last major boom in refining capacity. McKinsey forecasts that global refining capacity will increase by 5.1 million bbl/d between 2023 and 2028, but this increase includes 1.4 million bbl/d of announced capacity rationalisations, 90% of which are in OECD markets such as Europe and North America, with conversions to biorefineries and petrochemical production as well as the closure of older, simpler and less flexible refinery capacity. By 2030 as oil demand peaks, new capacity is likely to balance closures.

The impact on the sulphur industry will be profound. New refining capacity will add 4 million t/a of sulphur production from 2023 to 2028. In China in particular it will help drive increasing self sufficiency in sulphur and lower imports. But in the longer term we may simply see oil-based sulphur production gradually shifting from US and Europe to Asia, but remaining at a relatively steady output level ■

Handling liquid sulphur

Liquid sulphur presents unique challenges in its handling and transport compared to solid sulphur.

A liquid sulphur rail car.

PHOTO: GREENBLATT COMPANIES

Sulphur comes from a Claus plant in liquid form, and the feed to a sulphuric acid plant – by far the most likely destination for recovered sulphur – is also as a liquid. There is an argument, then, for transporting it from one place to the other in liquid form as well. However, shipping and storing liquid sulphur brings with it various challenges and expenses which have so far restricted its use to a few well-integrated routes.

Shipping solids

Transporting solid sulphur has the advantage of relatively low handling and storage costs. The sulphur can be stored in open areas, perhaps with side walls to shield the sulphur from prevailing winds, and can be moved using open conveyors. This means that quite large volumes can be stored fairly easily. Sea transport of solid sulphur is similarly subject to relatively fewer restrictions than liquid sulphur; regular single deck bulk carriers can be used, provided that precautions are taken for carriage of solid sulphur, such as some form of corrosion protection for handling machinery and hold spaces.

However, transportation in this way is also subject to various problems. Sulphur stored in the open is subject to contamination by dust and water, and potential losses. Sulphur dust is also a well-recognised fire hazard, and various sprays may be required at stages of storing and handling to prevent or minimise dust formation. If storage spaces such as ship holds are not properly pre-treated, there is the potential for serious corrosion of steel, and resulting costly and time consuming lime washes to treat it. Finally most sulphur is used molten by consumers, so customers must supply energy to re-melt the solid sulphur at the other end, and potentially remove various contaminants.

Shipping liquids

On the one hand, liquid sulphur is less corrosive, and being transported in enclosed systems poses fewer environmental risks. There is far less chance of contamination and no re-melting is required at the destination. However, it must be maintained within quite a narrow temperature range, of around 125-145 °C (and typically 135-140 °C). Around 158 °C sulphur undergoes a phase change and its viscosity rises very quickly, making it far more difficult to pump, while if the temperature drops there is the risk of the sulphur freezing solid, requiring long and expensive re-heating to melt it again.

Liquid storage obviously has limited capacity in heated tanks at source and destination, and so requires an integrated logistical arrangement, with coordinated storage on both sides and guaranteed transportation services.

Degassing

A prime concern for handling molten sulphur is the emission of hydrogen sulphide gas during loading of, e.g. trucks or rail cars. Nearly all molten sulphur contains some level of H_2S, and the agitation during transit or leading can result in the release of this hazardous gas. During the loading process, proper venting of H_2S to the atmosphere through a stack or to a scrubber or burner is essential for the safety of personnel, and it is also recommended that loading personnel wear a self contained breathing apparatus and do not rely strictly on mechanical means for their safety. Liquid sulphur is commonly degassed by passing air through it to convert H_2S into SO_2, reducing H_2S concentrations down to 10 ppmv before storage, compared with 250–300 ppmv in conventional sulphur pits, though dealing with SO_2 and increasing restrictions on SO_2 emissions can complicate the process. Even so, H_2S can accumulate in storage tank head spaces if the molten sulphur is stored for a long time, and air sweep techniques are necessary to prevent this from becoming problematic.

Tankers

International maritime laws on transport of liquid sulphur place significant restrictions on the ships that can carry it, and in practise it is shipped almost exclusively in dedicated vessels which are custom-built or converted for solely that task. Liquid sulphur is carried in separate tanks in the vessel's hold, anchored on rubber-containing pedestals to allow for thermal expansion. Thermal expansion can also affect both the structural strength and the capacity of the tanks. The hull is generally double- or triple-walled, compartments separated by transverse bulkheads with insulation to minimise heat loss.

Cargo temperatures are maintained between 130-140 °C to keep the sulphur molten and at low viscosity. The temperature is measured electrically using thermocouples, and connected to an alarm

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

system. Tanks, transfer pipes and valves must be temperature controlled at all times to keep from freezing shut.

In the past, steam was used to heat tanks and pipes, but this carries the risk of increased corrosion by formation of sulphuric acid with a leak, so many tankers have switched to an oil-based heating system for the main sulphur tanks.

The deck cargo pipe systems must also be insulated and heated to keep sulphur from solidifying. Generally this uses a skin effect electric heat tracing system, as familiar from many land-based sulphur pipelines, where an insulated conducing cable is run inside a ferromagnetic heating tube. The cable is connected to the heating tube at one end and a power source is connected between the cable and the heat tube at the opposing end. The inductive interaction between the current in the insulated cable and the return current in the heat tube causes heating which is then transferred to the neighbouring pipeline.

Other shipboard pipe systems use welded heating jackets, carrying steam, pressurised hot water, or hot oil.

Pipelines

Sulphur pipelines are used for transporting large volumes of sulphur over short distances, for example from a recovery plant to a forming plant. The main concern is keeping the sulphur molten over the distance and allowing for easy remelting should the pipeline become clogged. Several different heating methods can be used, mainly steam jacketing or skin effect heat tracing. Steam jacketing involves surrounding the 'core' or 'inner' pipeline carrying the liquid with a larger secondary pipeline or 'jacket'. Steam in the space between the two pipes keeps the transported substance at roughly the same temperature as the steam. Potential issues include the difficulty in identifying leakage points and failures, and cross-contamination can occur if a leak appears in the interior pipeline, contaminating the liquid sulphur with steam. Heat tracing is an electrical heating element run along the length of a pipe. It is typically less costly than the construction of jacketed pipelines, although it is dependent on a reliable electricity supply, and many loading sites have steam readily available.

Truck/rail cars

For long distance travel overland, liquid sulphur is shipped in trucks or more typically rail cars. This is particularly true in North America, where sulphur often travels from Canadian gas plants to US consumers by rail. As with shipping vessels, maintaining the sulphur temperature above 120 °C and below 150 °C is imperative, and the tank cars will be heavily insulated with rock wool or fibreglass, and equipped with electrical heating coils. The main hazards are associated with loading and unloading of the tank cars. Generally the sulphur is unloaded from the bottom of the car using a hose or insulated unloading arm. Cold spots throughout the loading arm must be minimised in order to eliminate the risk of the product hardening within the arm, and steam-jacketing or strap-on heating elements can be used to provide even heating within the loading arm.

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

Middle East Sulphur Conference 2024

PHOTO: CRU

Representatives from across the global sulphur and sour gas community convened in Abu Dhabi from 20 to 23 May to discuss and debate the key strategic themes that are driving the industry. The Middle East Sulphur Conference (MEScon) is a premier event that brings together representatives from the entire sour gas and sulphur value chain to promote technology and innovation, lessons learned, best practices, knowledge transfer and R&D.

The Middle East Sulphur Conference 2024, organised by CRU and UniverSUL Consulting and hosted by ADNOC, returned to the Conrad Abu Dhabi Etihad Towers for this premier sulphur event in the region which has become the epicentre of global sulphur and sour hydrocarbon production.

Day 1

This year's programme introduced some key new features on Day 1 of the conference, which is reserved for pre-conference workshops and interactive sessions.

MEScon Operations Roundtable

The MEScon Operations Roundtable was kicked off with an opening message from Angie Slavens, UniverSUL Consulting, who welcomed delegates and mentioned that this event is a throwback to the annual MESPON Operations Roundtable but done a little differently. The roundtable was chaired by Elmo Nasato, Nasato Consulting, and supported by industry experts from Amine Experts, ASRL, Axens, BASF, DuBois Chemicals, Enersul, Euro Support, and Worley Comprimo. The session promoted an open exchange of ideas, encouraging participants to share their operational experiences and challenges in the areas of gas treating, sulphur recovery, tail gas treating, sulphur forming and handling, and CO_2 capture. Each topic introduction by the panelists was followed by an open forum Q&A, fostering a collaborative atmosphere where attendees could learn from one another.

In addition to technical insights, the roundtable offered valuable networking opportunities. Conducting the session at the beginning of the event provided an opportunity for participants to identify key individuals to connect with over the course of the four day conference, presenting the opportunity to foster professional relationships and potential collaborations. The rich discussions and exchange of operational experiences ensured that delegates left with actionable insights and practical information to apply to their own facilities. The collaborative environment and expert-led sessions were instrumental in addressing current industry challenges and exploring innovative solutions, making the MEScon Operations Roundtable a success that is likely to be repeated in future years.

MEScon Sulphur Youth Majlis Session

The Sulphur Youth Majlis Session was a specially designed event aimed at inspiring and guiding young professionals, under the age of 38, as they explore career paths within the sour gas treating and sulphur industries. This session focused on fostering meaningful connections, providing valuable insights, and equipping attendees with the necessary tools for successful careers in sulphur. The session was initiated with a welcome message from Nasser Al Busaeedi, SVP of ADNOC Gas, who emphasised the importance of youth development in ADNOC, as well as the importance of sulphur to the organisation. A scavenger hunt then ensued, which served as an ice breaker to get people engaged and interacting with one another. When participants returned to the room, the Youth Panel was conducted, featuring up-and-coming young professionals in the industry: Al Sail Al Jaberi from ADNOC Sour Gas, Maryam Al Marzooqi from ADNOC Gas, Bader Alotaibi from Aramco, Feras Kordi from BASF, and Mahmoud Shafy from HEC. These individuals shared their career journeys, discussing what they love about their current roles, the challenges they face, their aspirations if failure was not an option, and the tools they believe are necessary for achieving their career goals.

Following the Youth Panel, an Expert Panel session, comprised of seasoned professionals with diverse career paths, was conducted. The panel included Mohamed Ashraf from Systems & Equipment, who discussed his entrepreneurial path; Rashed Bametraf from ADNOC Gas, who focused on technical operations; Rob Marriott from ASRL, who shared insights from an academic perspective; Elmo Nasato from NCL, who talked about innovation and R&D; Angie Slavens from UniverSUL, who addressed techno-commercial careers; and Ravi Srinivas from ADNOC Sour Gas, who discussed technical design. These experts provided insights into their career motivations, shared stories of influential mentors, and offered advice to young professionals in the sulphur industry.

Following the panel discussions, an engaging open forum Q&A allowed attendees to actively participate by asking questions and sharing their thoughts. Overall, the Sulphur Youth Majlis Session successfully inspired young professionals, provided them with valuable career guidance, and facilitated networking opportunities crucial for their professional growth in the sour gas and sulphur industries.

Aisha Alkayyoomi and Fatima Aldhaheri of ADNOC Sour Gas won the scavenger hunt prize, collecting all six correct answers in the shortest amount of time.

Arthur vas Asbeck of Paqell won the prize for best pipe cleaner sculpture with his H_2S molecule.

PHOTO: CRU

Industry experts provided young professionals with valuable career guidance at the Sulphur Youth Majlis Session.

BR&E Carbon Capture in the Sulphur Value Chain Workshop

BR&E's Ganank Srivastava and Mostafa Shehata conducted a reservation-only workshop session which reviewed the complete process flow of a sour gas plant, representative of the Middle East landscape. The workshop explored opportunities for implementing CO_2 capture plants along this value chain utilising BR&E's simulation tools. The workshop was fully subscribed, with around 40 attendees, who found it provided them with an interesting and unique perspective on the sulphur value chain.

Technical Showcases

Chaired by Frank Scheel, Worley Comprimo, this year's Technical Showcase session highlighted innovative advancements in the sulphur industry. Leorelis Vasquez and Nathan Smith from Worley Comprimo discussed carbon capture options for gas processing plants, focusing on reducing emissions and enhancing sustainability. Jan Kiebert from Sulphur Experts presented on the technical aspects of sweeping and shutting down sulphur recovery units (SRUs) through the tail gas treating unit (TGTU), emphasising plant longevity and operational efficiencies. Arthur van Asbeck from Paqell introduced developments in the Thiopaq O&G process, showcasing the use of biotechnology for more efficient sulphur recovery. Johann Le Touze from Axens presented the CRS 41 catalyst, explaining how its low-density TiO2 composition improves sulphur recovery efficiency. Finally, Majed Qaysi from Aramco highlighted orbital shaft machining technology for sulphur pelletisers, which enhances precision and durability.

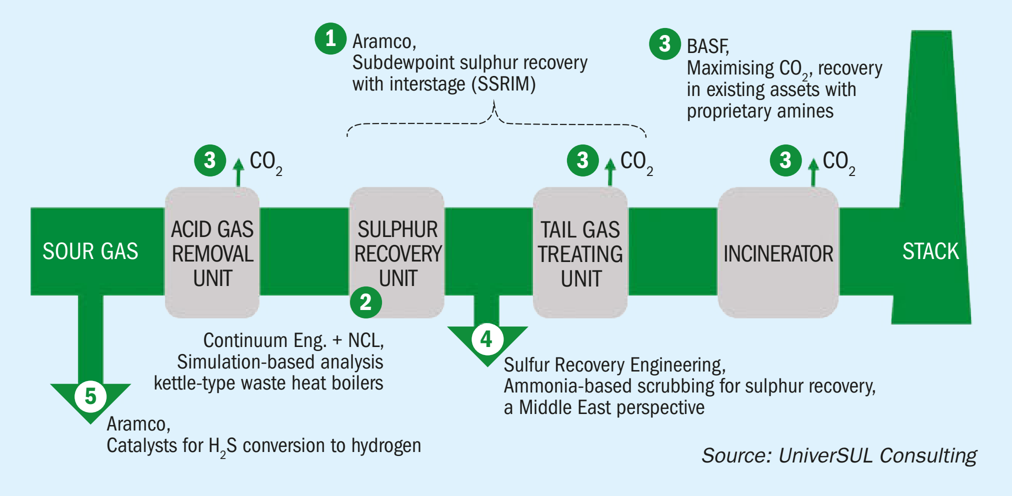
The session concluded with an engaging Q&A, allowing attendees to interact with the presenters and explore the innovations further.

PHOTO: CRU

Attendees representing 25 countries gathered at MEScon 2024.

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. 1: **Day 2: Innovative sour hydrocarbon strategies, technologies and design approaches**



Day 2

Day 2 marked the official opening of MEScon 2024. More than 650 delegates, representing 76 companies from 25 countries from across the sour gas and sulphur value chain, were welcomed through the doors of the Conrad Abu Dhabi Etihad Towers.

The event kicked off with opening speeches from ADNOC and Aramco, the two largest sulphur-producing companies in the world. Abdullah Al Messabi, CEO ADNOC Sour Gas, welcomed delegates on behalf of ADNOC, followed by Ahmed M. Al Wadeai, Director of Berri Gas Plant, who delivered Aramco's welcome. Both executives emphasised the importance of sulphur to their companies now, and in the future.

Fahad Al Wahedi, SVP & MEScon Executive Chairman, ADNOC Upstream, officially welcomed delegates to the MEScon 2024 event, followed by a MEScon kick-off presentation from Angie Slavens, UniverSUL Consulting and Al Sail Al Jaberi, ADNOC Sour Gas, who indicated that this event marks ten years of sulphur conferences in Abu Dhabi (between predecessor events MESPON and Middle East Sulphur – now combined to form MEScon). Key presentations in the morning session included an energy outlook by Michael Nevin, COO of io consulting, and a sulphur market overview by Dr Peter Harrisson, Principal Analyst at CRU. Other highlights of the morning session included insights on the new Hail & Ghasha Sour Gas Plant in UAE, the Tanajib Gas Plant in KSA, and Element 16's sulphur thermal energy storage technology, including a pilot project in Oman.

The afternoon took a look at novel approaches toward sour gas processing and sulphur recovery in the 'Innovative sour hydrocarbon strategies, technologies and design approaches' session. The paper topics presented in this session are shown in the graphic in Fig. 1. John O'Connell, Aramco, kicked off the session with a review of Aramco's SSRIM technology, which is aimed at achieving improved sulphur recovery for the subdewpoint process. Nasser Abukhdeir, Continuum Engineering, and Elmo Nasato, NCL, then presented an innovative approach toward evaluating the water side of SRU WHBs. Ashraf Abufaris and Feras Kordi, BASF, then presented a case study on recovering CO_2 from existing assets utilising OASE solvents. Following the afternoon break, Inshan Mohammed, SRE, presented an evaluation of ammonia-based tail gas treating technology. Aramco's Anton Manakhov wrapped up the session with a presentation describing Aramco's development of a catalyst designed to convert H_2S to H_2.

The day wrapped up with the daily quiz, which was won by Johann Le-Touze of Axens.

Day 3

Day 3 began with a flurry of new participants eager to join the morning deep dive into gas treating in the 'Gas treating excellence from wellhead to SRU' session, which was moderated by Dr Rob Marriott, ASRL. The paper topics presented in this morning session are shown in the graphic in Fig. 2. Saeed Al Bloohshi, ADNOC Sour Gas, kicked off the session with insights into sour gas pipeline inspection procedures at Shah. Oxy's Seth Spear then presented a novel approach to acid gas injection using ejectors. Ibrahim Khan, ADNOC Gas, then described recent efforts to improve acid gas removal operations at Habshan by enhancing mass transfer in the absorber. Ben Spooner, SGS Amine Experts, shared an interesting case study to prolong the life of an existing amine regenerator which was experiencing high corrosion rates due to heat stable salts. Worley Comprimo's Jon Lewis then gave a talk on mercaptan removal options and Aramco's Bader Alotaibi wrapped up the session with an innovative approach to stripping amine of H_2S prior to shutdown.

Prior to lunch, a Poster Spotlight was conducted, allowing all poster presenters to give a five minute brief on their digital posters which were presented on monitors during the exhibition. Four posters by Aramco and one poster by AIMS were presented during this session. Participants crowded around the speakers in the exhibition area during breaks to listen intently about their case studies, an opportunity for the audience to learn directly from operating and supplier companies.

The afternoon session took a look at digitalisation and automation advances in the 'Sulphur Industry 4.0' session, which

Fig. 2: **Day 3: Gas treating excellence from wellhead to SRU**

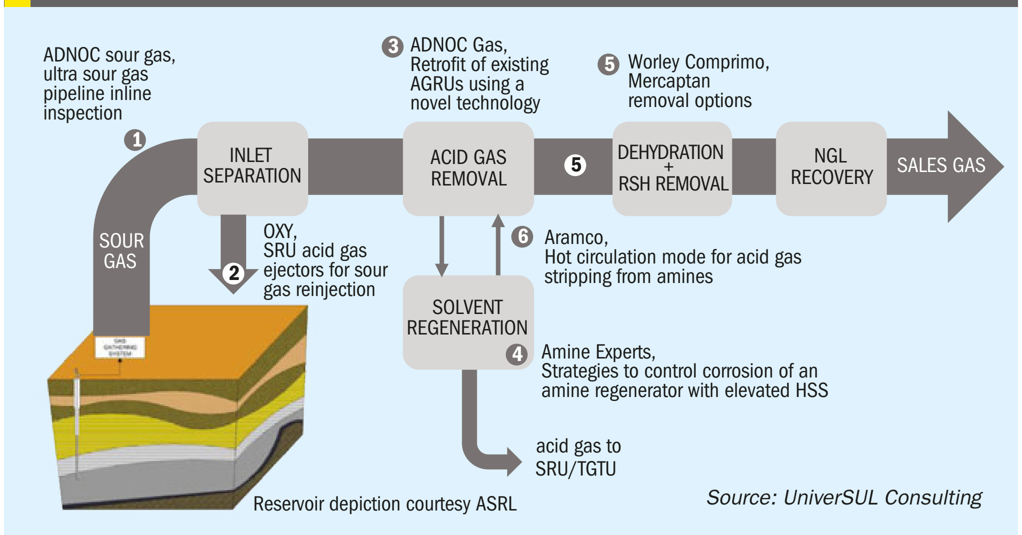
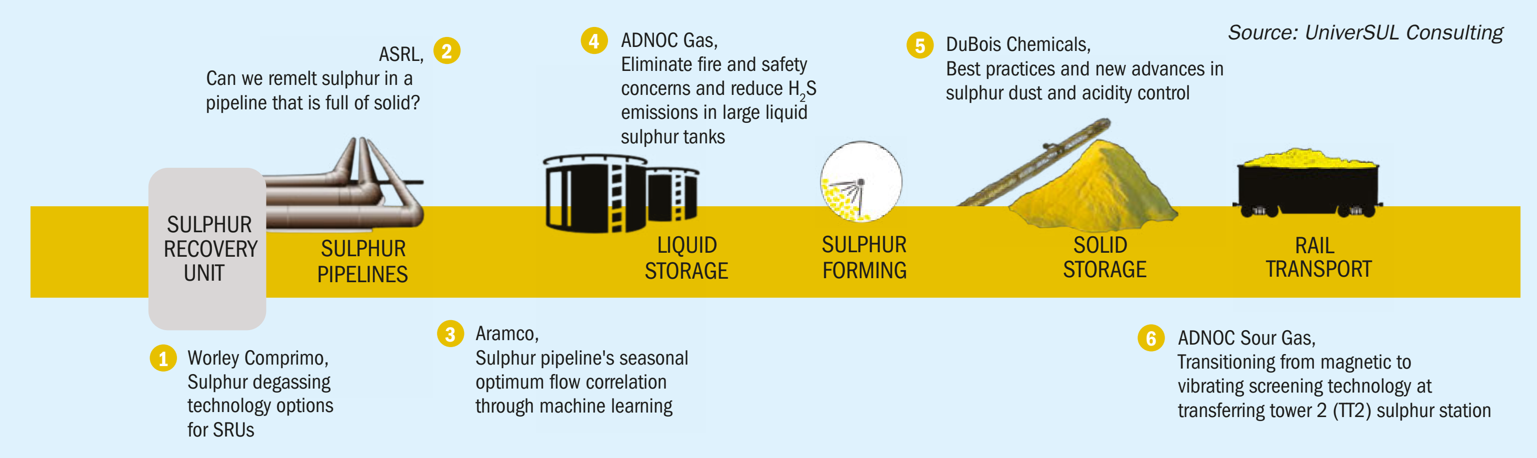


Fig. 3: **Day 4: Sulphur handling experience from the world's largest producing region**



was moderated by Yasin Al Awadhi of ADNOC. Topics on AI, machine learning, automation, digital dashboards, and linking simulation with plant data were presented by ADNOC Gas, Aramco and BR&E. An audience poll conducted during this session indicated that the audience believes the Middle East is farther along in implementation of these types of tools in sulphur plants than are other parts of the world.

The daily quiz was won by John O'Connell of Aramco.

Day 4

The final day of the conference saw strong attendance, with participants eager to engage in discussions related to sulphur handling and best practices in SRU/TGTUs. Opening remarks were provided by Ahmed Basioni, SVP of ADNOC Sour Gas.

Angie Slavens of UniverSUL Consulting mentioned that the opening session 'Sulphur handling experience from the world's largest producing region' is special in this part of the world because it is one of the only places where we can take a deep dive into all steps of the sulphur forming and handling process due to the large number of massive sulphur handling facilities in the region. The session (see Fig. 3 for overview) was chaired by Saood Al Marzooqi, ADNOC Sour Gas and covered topics from sulphur degassing (Marco van Son, Comprimo), sulphur pipeline remelt (Dr Rob Marriott, ASRL), sulphur pipeline seasonal optimum flow (Bader Alotaibi, Aramco), sulphur tank venting best practices (Pankaj Kumar, ADNOC Gas), advances in sulphur dust and acidity control (Jeff Cooke, DuBois Chemicals), and magnetic vs. vibrating screening at Shah's complex (Mohammed Al Booshi, ADNOC Sour Gas).

Poster spotlights were presented by Aramco, ADNOC Sour Gas and BR&E, once again showcasing a wide range of operations topics which allowed delegates to hear case studies and lessons learned directly from the field.

After lunch, the final session on 'Best practices in SRU/TGTU operation and design' was chaired by Elmo Nasato, Nasato Consulting, and comprised four papers (Fig. 4). KNPC's Saad Almutairi kicked off the session with a presentation on troubleshooting an SRU burner at the KNPC MAA Refinery. Ametek's Jochen Geiger then gave an historical account of the developments in SRU/TGTU analysers and suggestions for modern best practices. Muhammad Nisar of ADNOC Sour Gas discussed challenges related to water carryover from their WHBs at higher than design acid gas feed rates and Evonik's Brian Visioli wrapped up the session with a presentation on the optimum, holistic approach to evaluating catalyst requirements.

The final daily quiz was won by Rashid Rajhi of PDO and scavenger hunt prizes were awarded to Ayesha Alkayoomi of ADNOC Sour Gas (1st place) and Shailesh Dayal of Blasch (2nd place).

Adel Al Jaberi, SVP ADNOC Sour Gas, gave the closing remarks, thanking delegates and participants and expressing ADNOC's continued commitment to the event. ■

Fig. 4: **Day 4: SRU/TGTU best practices in operation & design**

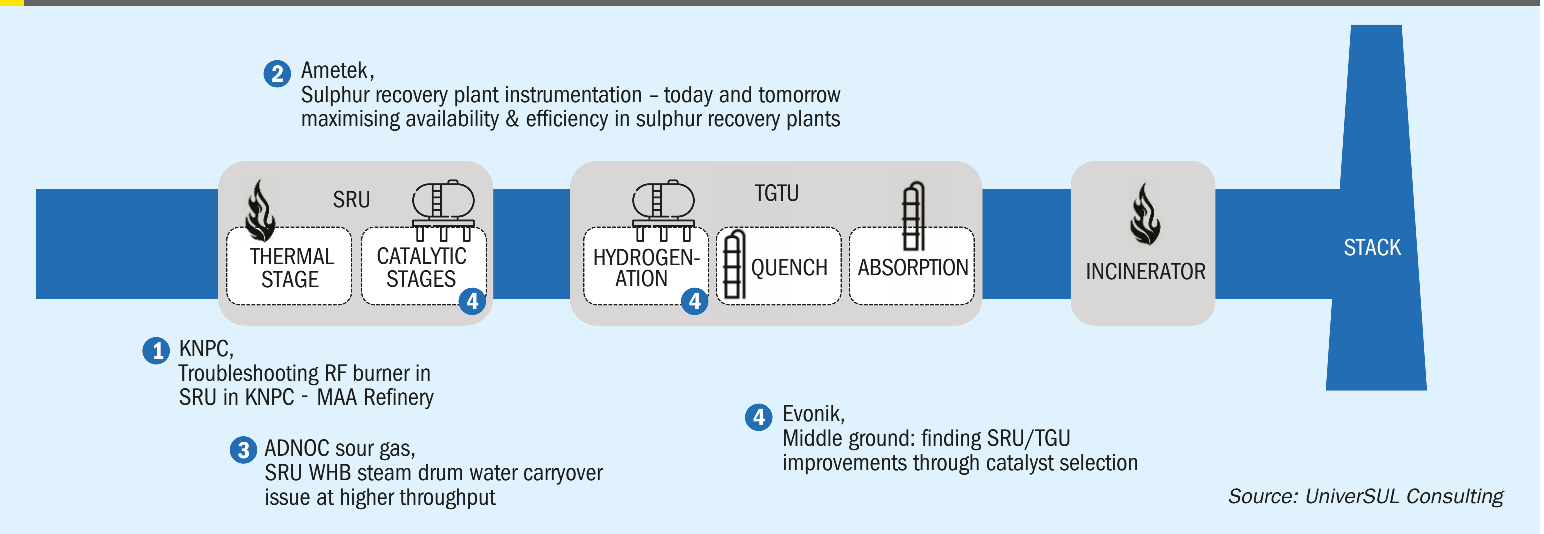


PHOTO: COMPRIMO

100 years of Comprimo

As Comprimo celebrates its 100th anniversary, we explore the group's history from its earliest days in the Netherlands in the 1920s to its current status as a global leader in gas treatment and sulphur recovery technology.

Kuwait Petroleum Europoort, sulphur recovery unit by night in the Netherlands

The name "Comprimo" is one very familiar to those involved in the gas treating and sulphur industry. Nearly all gas plants and refineries worldwide operate at least one unit designed by Comprimo, which represents more than 60 percent of licensed sulphur recovery units globally and has played a major role in reducing H_2S and SO_2 emissions since the 1950s. Comprimo, founded 100 years ago in Amsterdam, derives its name from the Dutch term "comprimeren," which refers to industrial cooling by gas compression.

Comprimo is part of a rich history of engineers and engineering companies in the Netherlands and world renowned for its expertise and legacy in the sulphur industry. Through multiple mergers and acquisitions over the years, the Comprimo name remains to recognise the company's legacy. It has survived 100 years of industry change and disruption, a testament to its enduring significance and contributions to the field of engineering.

The beginning

On the 16th of July, 1924, Mr G. L. Tegelberg, Director of N.V. Geveke & Co., and Mr J. Muysken, Director of N.V. Nederlandsche Fabriek van Werktuigen en Spoorwegmaterieel founded N.V. Comprimo, a company specialising in refrigeration and chemicals. The company's main shareholder was initially N.V. Geveke, while the first director of Comprimo was Mr. G. Cattaneo. Comprimo's first office was established at N.V. Geveke's headquarters in Amsterdam at De Ruyterkade 113, in five rooms on the second floor of the building, with "the lovely view of the railway complex" noted in articles on the founding of the company.

After demonstrating expertise in designing industrial-scale refrigeration units and their associated compressor units, Comprimo soon grew and expanded its horizons into new projects. It gained contacts with nearly all major companies in the Netherlands and Europe at large, helping Comprimo become a multifaceted engineering services provider for the energy and chemicals industry. In particular, the so-called "Edeleanu units" were instrumental in transforming Comprimo into the first multi-disciplinary engineering contractor in the Netherlands. By the 1950s and '60s, Comprimo's contributions to the oil and gas industry were widely recognised and the company had expanded to having multiple offices in both Europe and the Middle East. Additionally, Comprimo developed subsidiaries to specialise in endeavours like nuclear energy and district heating.

At Comprimo's 50th anniversary in 1974, a collection of Comprimo's achievements and capabilities was assembled, displaying its expertise in nearly every discipline of technical knowledge and application. Attention was further drawn to its involvement in the many projects that shaped the industrial landscape of both the Netherlands and world at large. Some of the landmark projects that followed in the 1980s and '90s were the Per+ expansion of the Shell refinery in Pernis and Demkolec gasification plant in Buggenum. These achievements further raised Comprimo's distinguished reputation.

Comprimo as a technology licensor

The company today known as Shell became one of Comprimo's customers during the 1930s; at the time, it was called "de Bataafse Petroleum Maatschappij." This cooperation intensified after the Second World War during the 1940s and '50s and eventually led to Shell becoming a major shareholder in Comprimo. Some of the major projects to come out of Comprimo's work with Shell were efforts to fight acid rain, the result of when sulphur-related emissions, like SO_2 and H_2S, are "washed" out of the sky by rainfall. This creates sulphuric acid that damages crops and buildings, and acidifies various water sources. Comprimo's work with

Shell on projects such as this built a relationship that eventually led Shell to invite Comprimo to manage the licensing of Shell technologies to third parties. Thus, Comprimo as a technology licensor for sulphur recovery units was born.

In the years that followed, Shell and Comprimo further developed the modified Claus process and created additional technologies to clean natural gas and industrial off-gases from sulphur, its related elements, and other contaminants dangerous to the atmosphere. As countries developed legislation on emission criteria, Shell and Comprimo became industry leaders in designing and deploying emission reduction technologies. While initially done via Shell facilities, this endeavour soon expanded internationally.

As Shell developed technologies to enhance its various production facilities, other oil and gas producers inquired about using this technology themselves. This led Shell to commercially license out its technologies. Comprimo was asked to oversee the licensing of technologies related to gas processing, sulphur recovery, and emission reduction. Among them were Shell's sour gas treating and tail gas treating solutions, predominantly amine-based absorption regeneration technologies. Together, Shell and Comprimo further developed and optimised the Claus sulphur recovery process, helping them become global leaders in developing and commercially licensing these technologies. This leadership position led both companies to play a major role in fighting acid rain issues during the 1970s and '80s. The technologies and processes developed during this period still form the basis of gas treating and sulphur recovery projects today across the world.

Comprimo in the last decades

Comprimo's journey as a technology licensor started in the mid-1950s. Ever since, the Comprimo team has worked to improve the technologies it licenses and increase sulphur recovery efficiency. However, first and foremost its goal is to reduce SO_2 emissions into the environment. Sulphur recovery and gas treating remains crucial to refinery and gas plant operations, and as a result, is a necessary cost required to stay in business. Because of their importance, these units must be extremely robust with the highest safety and reliability requirements.

The constant drive for better energy efficiency and tighter emission norms have pushed the Comprimo team to develop technologies that comply with industry regulations, while being widely available to the companies that require their use.

In the 1980s, Comprimo developed the SUPERCLAUS process, providing operators with an affordable, fully catalytic solution that was compliant with contemporary emission expectations. This technology is still widely used and has seen constant improvement over the years. Other developments of the 1980s are the low temperature tail gas treatment and sulphur degassing technology, both developed with Shell.

In 1995, Comprimo became a part of Stork Engineering & Contractors. During this period, the name "Comprimo" was phased out as the group was assimilated into the "special projects" department at Stork Engineering, where the SRUs they developed were sold internationally as a lump sum turn key (LSTK) solution. In 2000, another acquisition had the Dutch Stork Engineering offices, which included Comprimo, become part of Jacobs Engineering Inc. The Comprimo name was restored, in appreciation of its legacy and value among licensees and potential new customers. "Comprimo" as a name had become associated with sulphur recovery units as a recognition of the quality, robust technology behind them.

Additionally in 2000, Jacobs acquired Delta Hudson, a Canadian company active in the gas treating and sulphur recovery field. To better serve markets in the Americas, a Comprimo department was established in Calgary. By this point, Comprimo as a name was fully reintroduced to the industry. The new full official name was "Jacobs Comprimo Technology Solutions," but the shortened "Comprimo" remained its name in common conversation.

The specific skills of the Comprimo team, which involved preparing high quality process design packages that allow FEED and EPC contractors to build Comprimo-designed plants, soon gained notice in the industry. Requests came in to provide these services across the field; these requests grew in volume with the acquisition of Aker Solutions by Jacobs. In 2012, a team was formed to provide services for third party licensing and technology scaling. The Comprimo team has since been working on providing one-of-a-kind process design packages and technology scale-up designs for newly developed technologies.

During this period, Comprimo's sharp growth and subsequent increased workload created a need for highly skilled technical workers that traditional technology centres could no longer provide. As a result, Comprimo began a close cooperation with offices in India. Since 2006, a dedicated team there has been trained to help support Comprimo's global technology business.

Reducing emissions and enabling sustainable energy production

Recently, Comprimo, as a part of Jacobs's Energy Chemicals and Resources business, was acquired by Worley. This brought together the two major players in the field of technology licensing for gas treating and sulphur recovery: Comprimo Sulphur Solutions and WorleyParsons Gas Treating and Sulphur Group. Jointly, these two groups have licensed more than 1,200 units for their global customer base; some of these units are among the largest in the world, producing over 3,000 t/d of sulphur in a single train. These accomplishments have made Comprimo a leading global voice for advice on gas processing and reducing both SO_2 emissions and CO_2 footprint.

This legacy places Comprimo at the heart of the challenging balancing act faced by global energy suppliers: the demand for cleaner energy that simultaneously appreciates developing countries' intense energy requirements to create a higher standard of living. In the coming decades, these demands will require unseen new heights for technologies and cooperations, providing an environment where the Comprimo spirit of cooperation and technical excellence is key to success.

Currently, Comprimo is working on some of the world's biggest initiatives for gas and LNG production while simultaneously supporting its customers to reduce CO_2 emissions and conduct hydrogen recovery. In tandem, Comprimo is working with many of its existing licensees to optimise their energy use, reduce emissions and process new energy sources like bio feedstocks to produce biofuels. Comprimo is also working on developing and deploying novel technologies like plastic recycling, small-scale gas cleaning, affordable CO_2 capture, and hydrogen recovery.

PHOTO: COMPRIMO

Kuwait Petroleum Europoort, sulphur recovery unit module hoisted to its place in the Netherlands

PHOTO: COMPRIMO

BEB Grossenkneten Germany, tail gas treating unit 1550 t/d

PHOTO: COMPRIMO

Turkmengaz – Large SUPERCLAUS® unit in Turkmenistan

A front runner in solutions for sustainable fuel and hydrogen production

The engineering office in the Netherlands, now called Worley Nederland B.V., has grown to an entity of more than 1,200 people with a long history of both large and small projects in the energy and petrochemical industry. The enduring relationship with Shell is still strongly maintained, and Worley has also developed partnerships with many of the world's largest oil, gas, chemical, and energy companies. As a result, Worley is now a frontrunner in developing and realising flagship projects related to new energies and renewable chemicals. The teams in the Netherlands, together with Worley's worldwide network, are now at the centre of a global movement toward cleaner energy that maintains efficiency.

Comprimo now has four branch offices in Los Angeles, Calgary, London, and The Hague. All comprise a part of the global Worley organisation with a total strength of more than 50,000 employees. Comprimo is part of the Technology Solutions group within Worley and works together with the Worley engineering and consulting departments. The group's spirit of collaboration and innovation has ultimately created an environment where close cooperation and flexibility defines its approach to scope, development, and implementation, and supporting Worley's purpose of delivering a more sustainable world.

Boosting sulphuric acid production with oxygen

A plant operating a spent acid decomposition furnace as part of its sulphuric acid production facility desired to increase acid production primarily by processing additional spent acid while making minimal modifications to the plant equipment and operations. The Messer solution entailed introducing oxygen in two steps, both as an enrichment to the combustion air and by direct injection into the furnace. The resulting performance improvements exceeded the project objectives for acid production and spent acid decomposition, without increasing NOx emissions. This paper provides a summary of the system start-up and tuning and presents the resulting improvements and lessons learned.

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Sulphuric acid is used in petroleum refining as a catalyst for the alkylation of isobutane with C_3-C_5 olefins to produce higher octane gasoline for motor vehicle use. The process causes the sulphuric acid to become "spent" as it is contaminated with impurities such as water and hydrocarbons. Disposal of spent acid is not economical, and the preferred solution is to regenerate it in a spent acid recovery (SAR) unit. In recent years the volume of spent acid production has increased significantly. The investment required to construct new SAR units can be prohibitive, so production facilities look for opportunities to increase the capacity of existing equipment.

The first step in the SAR process consists of a decomposition furnace in which the spent acid is converted to sulphur dioxide (SO_2), which is subsequently cleaned, oxidised to sulphur trioxide (SO_3) and ultimately used to produce fresh sulphuric acid. Other sulphur-containing streams such as raw sulphur may also be introduced into the furnace to increase the amount of SO_2 produced. Since the decomposition of the spent acid is endothermic, supplemental fuel is required to maintain the furnace outlet temperature. An increase in the production capacity of the SAR decomposition furnace may be limited by operational, product quality or environmental constraints that cause bottlenecks in the process.

There are well-established strategies for increasing the capacity of a furnace to decompose more spent acid. One is to preheat the combustion air to improve thermal efficiency by reducing the amount of fuel required. This accounts for the additional heat needed for the reaction, but there are practical limits for the maximum temperature to which the air may be heated. Another strategy is to supplement the combustion air with excess oxygen, which provides a way to increase the amount of oxygen available for reaction while reducing the overall volume of the combustion air due to the corresponding decrease in the combustion air nitrogen volume. This allows more fuel to be fired in the furnace to generate the necessary heat to decompose more spent acid. However, there are safety concerns that limit the extent of oxygen enhancement in the combustion air.

Both approaches allow for more spent acid to be decomposed while maintaining the appropriate levels of furnace exit gas temperature (FEGT) and excess oxygen concentration, without significantly increasing the pressure drop across the furnace. Unfortunately, they each result in higher adiabatic flame temperatures and lead to higher rates of NOx formation. Higher NOx can lead to product quality concerns in the form of increased nitre concentration in the acid produced. Facilities with stringent environmental regulations are not able to increase their NOx emissions and must therefore innovate to achieve their spent acid processing goals.

The reference plant operates an SAR unit in which the spent acid decomposition furnace was the primary bottleneck preventing the plant from achieving its authorised acid production rate and limiting the rate at which spent acid could be processed. The customer performed process simulations that indicated the potential to increase throughput by oxygen enrichment, thereby increasing the amount of spent acid feedstock for sulphuric acid production. Since Messer has a long history of working with the customer to supply industrial gases and technology solutions, the company reached out to

Messer for assistance with the analysis. The project team, with decades of NOx control experience, ran several additional process simulations and used CFD modelling to test alternative solutions. These iterations helped Messer determine the conditions needed for the furnace to process more spent acid, produce more SO_2, and meet the existing operational and environmental constraints.

Process description and objectives

The plant is equipped with a spent acid decomposition furnace for producing SO_2. The furnace has a cylindrical shape and is divided into multiple segments by internal walls designed to redirect the streamlines of the combustion products to increase residence time and to achieve the desired mixing level. The furnace is equipped with multiple burners which fire a mixture of a fuel and preheated combustion air. There are multiple ports through which spent sulphuric acid or other sulphur-containing streams may be injected. To maximise the conversion of the input streams to SO_2, the furnace exit gas temperature and excess oxygen concentration are maintained at typical conditions to maximise SO_2 production.

The capacity improvement project presents multiple challenges. Increasing the production of pure sulphuric acid requires a greater volume of SO_2 exiting the furnace. This is problematic because the entire SAR process train is fan limited, meaning that the existing fans that move the gases through the process are operating at the maximum pressure drop. Increasing the amount of spent acid that can be introduced into the furnace as a feedstock is challenging because the decomposition of the spent acid is endothermic, so additional fuel must be fired to supply the necessary heat to complete the reaction and maintain the desired FEGT. The combustion products of the fuel increase the volumetric flow rate and result in a higher pressure drop and lower residence time through the fixed geometry components of the SAR process train. This also has a negative impact on the performance of the downstream process equipment. Higher firing rates through the existing burners can elongate the flame such that it impinges on the back wall of the first mixing chamber in the furnace. This can result in materials of construction issues along with poor combustion quality and an increase in products of incomplete combustion.

The ability to achieve the objectives was further constrained by the NOx mass emission limit. Raising the concentration of oxygen in the combustion air entering the burners causes the adiabatic flame temperature to increase and results in higher NOx emissions. Increasing the amount of fuel fired to decompose additional spent acid has a double-negative effect. Assuming the NOx emission rate remained unchanged on a mass per unit of heat input basis, a higher fuel rate would generally produce a linear increase in the NOx mass emissions. However, a higher fuel firing rate also results in a larger, hotter flame and produces higher rates of NOx formation per unit of heat input, so the impact of higher fuel flow is compounded. Therefore, to prevent the NOx mass emission rate from increasing, the rate of NOx formation on a mass per unit of heat input must actually be decreased.

Approach

As noted previously, the SAR unit is limited by the capacity of the existing fans to push more gas through the process. The use of pure oxygen to displace a fraction of the decomposition furnace combustion air is an established solution that has dual benefits associated with the reduction in the amount of nitrogen passing through the process. The oxygen enrichment of the combustion air allows the process to operate more efficiently with less nitrogen acting as a heat sink, and the volume of nitrogen that is removed can be replaced with additional volumes of SO_2, leading to higher production capacity.

The decomposition furnace utilised multiple sulphur-containing feedstock streams that contributed to the total amount of SO_2 and ultimately pure acid produced by the process. Of the streams, the spent acid is the most economical source of sulphur because it is a revenue source for the facility. Other feedstock may be cost-neutral or considered to be an operating expense. The calculation of the financial benefit is further complicated by the need to account for the additional fuel required for the endothermic spent acid decomposition reaction, whereas the oxidation of some sulphur-containing feed streams is an exothermic reaction that contributes heat to the process energy balance. When all factors are considered, an SAR plant's most lucrative operating mode is one in which the amount of spent acid processed is maximised.

The economic benefit of using an existing SAR unit to produce more pure acid while using higher feed rates of spent acid is obvious. Although, since both spent acid decomposition and acid production result in higher volumetric flow rates, the solution for achieving these benefits with a fan-limited process is less straightforward. The potential improvement from oxygen enrichment can be determined using a simple simulation for the mass and energy balance.

However, a simple simulation is not capable of predicting the higher rate of NOx formation that results from the impact of oxygen enrichment on the adiabatic flame temperature. Even if the impacts of higher NOx on the product quality and the environment are not considered, there are material and safety limitations to the amount of oxygen that can be mixed with the combustion air upstream of the burners.

Since the process requires higher amounts of oxygen enrichment and the amount of oxygen that can be mixed with the combustion air has practical limitations, it follows that some of the oxygen must be introduced separately from the burner. This approach requires the application of a complex CFD simulation with numerous submodels that are utilised to determine temperature and gas concentration profiles in the furnace to identify the appropriate location and manner of injection for the additional oxygen.

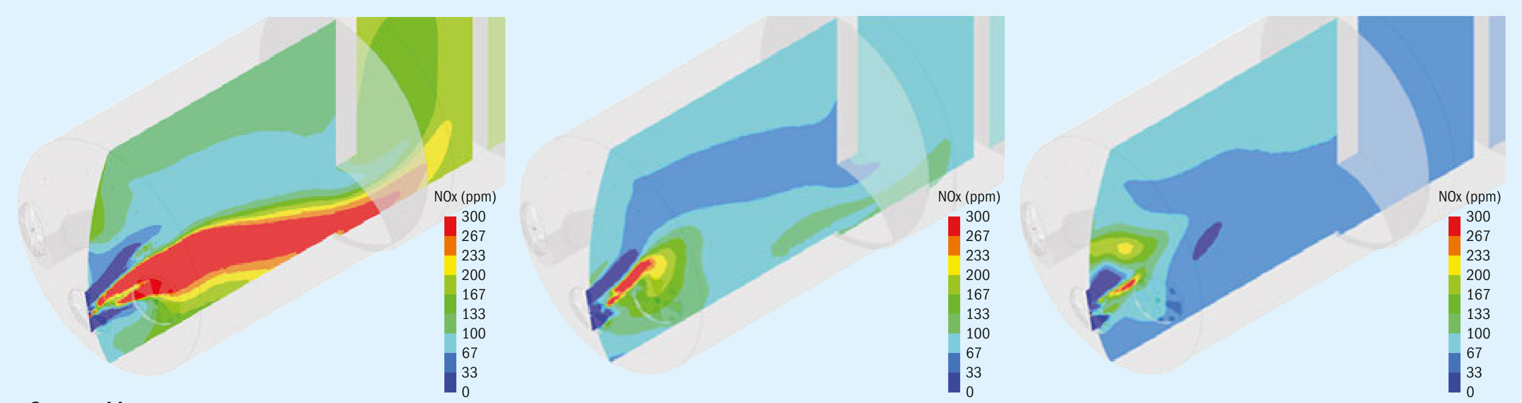
Process simulations

To achieve the stated objectives numerous factors need to be evaluated:

- the amount of additional fuel that must be introduced to supply the heat for decomposing the higher spent acid rates;
- the amount of oxygen needed to offset the higher SO_2 volume produced in the furnace;
- the amount of oxygen that should be added to the combustion air compared to how much is injected directly into the furnace;
- how to inject the oxygen into the furnace to maintain the existing mixing and reaction chemistry while reducing the rate at which NOx is formed.

Each of these factors must be continually re-evaluated as the process conditions change (e.g., the overall production rate or the relative amounts of spent acid, raw sulphur and any other sulphur-containing feed streams that are being fed to the furnace).

Fig 1: NOx concentrations for baseline and two alternative configurations



Source: Messer

A two-step process simulation approach was utilised to evaluate the aforementioned factors and provide insights that would inform the design and implementation of the system. In the first step, Unisim was used to establish the mass and energy balance for the decomposition furnace. These values were then input into CFD models of the process containing about four million computational cells. The models incorporated numerous submodels, including those for chemical reactions, two-phase flows, turbulence, radiation, wall conditions, droplet vaporisation, and NOx formation.

Post-processing of the model results provided graphical depictions of numerous furnace conditions such as velocity vectors and temperature profiles, along with species concentrations including oxygen, sulphuric acid, SO_2, NOx, and fuel. The baseline operation of the furnace was modelled, and then the furnace parameters were adjusted to reflect the changes in spent acid feed rate, the amount of oxygen injection, and the overall acid production rate. The results were used to indicate how changes to the location and amount of oxygen introduced into the furnace would affect the overall process conditions. In particular, the relative predictions for the NOx formation rate proved valuable in developing the design of the system. Fig. 1 presents some of the results of the CFD simulations.

Apparatus

The process simulations provided the information used for the design of the oxygen supply and injection system. The supply system provides gaseous oxygen on demand to a metering skid controlled by the plant distributed control system (DCS). The metered oxygen is piped from the skid to a manifold adjacent to the decomposition furnace. There are two sets of metering skids and manifolds, one for the oxygen enrichment of the combustion air and the other for the oxygen injection into the furnace. The oxygen flows from the enrichment manifold to a sparger located in the combustion air duct. CFD modelling was used to design the sparger so that the oxygen mixes completely with the combustion air prior to where it splits to supply the individual burners. The furnace manifold has multiple outlets so that oxygen may be delivered to more than one location simultaneously. The furnace injectors are designed to penetrate the furnace wall by a specified amount and are manufactured from a higher alloy that allows them to survive the conditions in the furnace. They deliver a sonic flow of oxygen to achieve the desired distribution and mixing with the gases in the furnace interior. The DCS is programmed to control the oxygen flow for a given operating condition and the corresponding decrease in the amount of combustion air needed. The DCS also determines the split in the fraction of oxygen used for combustion air enrichment, while the balance is injected into the furnace. The oxygen supply program works within the existing operating control parameters of the system that maintains the proper temperature and excess oxygen concentration at the furnace outlet.

Presentation of results

The demonstration focused on two primary objectives. The first was to determine the effectiveness of additional oxygen for increasing process capacity. The goals for the capacity increase consisted of two subparts, one of which was the ability to process greater volumes of spent acid while the second was to produce higher amounts of pure acid.

Since there are multiple sources of sulphur being fed to the furnace, the increase in spent acid consumption was not linearly related to the sulphuric acid production rate. This was fortuitous due to the greater number of process constraints limiting the pure acid production as compared to the ability to process spent acid. The second primary objective was to maintain the NOx emission rate at or below the baseline levels. Due to the additional heat input required to process more spent acid, the NOx concentration had to decrease on a lb/MMBtu basis to maintain the same mass emission rate. The results associated with each of the primary objectives are presented in the following sections, and the data presented have been normalised to protect the site's process information.

Processing capacity improvement

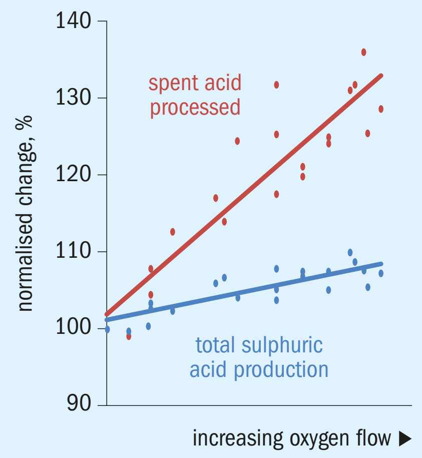
The testing results of increasing both the acid production and the rate of spent acid processing are presented in Fig. 2. (Please note that these operating conditions are the same in all subsequent figures.) The trend lines represent a linear fit of the individual data points collected. At each condition, the primary variables were the oxygen flow rate and the amount of spent acid and other sulphur-containing feed streams. The process air and fuel flows were then adjusted to maintain the target FEGT and excess oxygen concentration. The process was allowed to reach steady conditions and then held for a sufficient time to obtain an accurate representation of the resulting performance. One-minute averaged data were collected by the DCS and these were later extracted and averaged over the duration of the individual test condition to produce the data points presented in the figure.

Fig. 2 shows a moderate improvement in the sulphuric acid production rate as the oxygen flow rate was increased. These data are somewhat misleading because the sulphuric acid production rate was intentionally restricted due to a number of constraints that occurred futher downstream in the process. These bottlenecks prevented the process from sustaining the maximum sulphuric acid production, and most of the testing occurred at rates less than 10% above baseline. However, some shorter-term results were obtained that suggested that a 15% increase was readily achievable.

The limitation of the sulphuric acid production rate was accomplished by reducing the rate of the other sulphur-containing feed streams to offset most of the additional sulphur entering the furnace as spent acid. This represented a preferred mode because the other feed streams are typically either an operating expense or cost-neutral but plants receive payment to process spent acid. Factoring in the oxygen cost and the additional fuel required to decompose the spent acid, the economics of this scenario were far superior to the baseline.

Variability in the spent acid data is generally due to changes in other process variables. For example, there were often test conditions in which different spent acid flow rates were evaluated at a single rate of oxygen flow. Since some of these test conditions are not representative of the 'ideal' at a particular oxygen flow rate, the slope of the trend line skews slightly lower than what would be achievable under normal operating conditions. Even so, the data shows that the performance target of 30% increase in the spent acid processing rate was achieved.

Fig 2: Increased spent acid processing and sulphuric acid production with oxygen addition



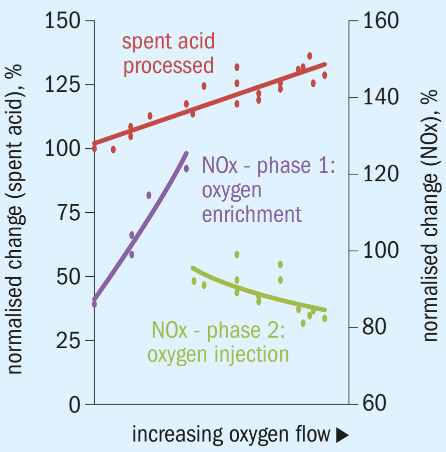
Source: Messer

Emissions reduction

The primary challenge for increasing the spent acid processing rate was the regulatory requirements that limited the amount of NOx emissions. As described previously, both increased oxygen in the combustion air and the higher fuel firing rates required to decompose the spent acid tend to increase NOx formation rates. A key aspect of the demonstration was to determine how well the NOx could be managed by a combination of oxygen enrichment of the combustion air and direct furnace oxygen injection. Fig. 3 illustrates the outcome of that evaluation. Note that the normalised spent acid scale is presented on the left-hand y-axis and the normalised NOx mass emission rate is on the right side of the plot. The initial testing focused on adding oxygen to the combustion air as the spent acid rate increased. As expected, this caused the NOx emission rate to increase dramatically, and the testing had to be suspended to avoid exceeding the time-averaged regulatory limit. The results showed that with oxygen enrichment of the combustion air, only a 5% to 10% increase of spent acid could be achieved before exceeding the target NOx limit.

The next phase of the evaluation was to begin switching some of the oxygen supplied to the process from combustion air enrichment to direct furnace injection. As seen in Fig. 3, the furnace oxygen injection had an immediate effect in reducing the rate of NOx formation and the mass emission rate of NOx continued to decrease with increasing oxygen flow. This is significant because the reduction in NOx is occurring while the spent acid processing rate and the corresponding fuel firing rate are both increasing. These conditions also align with those presented in Fig. 2, in which the pure acid production rate has increased by 5% to 10%. Therefore, the NOx concentration is decreasing even more dramatically than that depicted by the mass emission data in the figure. The conditions shown in the figure are all at steady state while the operators were able to maintain the FEGT and excess oxygen concentration at their normal targets.

Fig 3: NOx emissions for oxygen enrichment vs. injection



Source: Messer

The CFD modelling indicated that there are two primary drivers associated with direct furnace oxygen injection for the reduction in the NOx formation rates. The first is the change in the stoichiometric ratio of air to fuel in the primary flame zone. The amount of combustion air decreases as the oxygen flow rate increases, and when the oxygen is injected directly into the furnace there is much less air/oxygen being introduced through the burner. This results in the burner flame stoichiometry being less fuel lean, causing a scarcity of available oxygen for NOx formation. At the same time, the oxygen injected at other locations in the furnace allows for the combustion process to be completed in the first chamber at lower temperatures which are less conducive to NOx formation. The scarcity of oxygen in the flame also helps prevent the oxidation of any fuel-bound nitrogen to NOx. The second driver in the rate of NOx formation revealed by the CFD results is that the volume of the high-temperature flame zone is greatly reduced. The smaller volume translates to less time for nitrogen to dissociate and potentially be oxidised to form NOx.

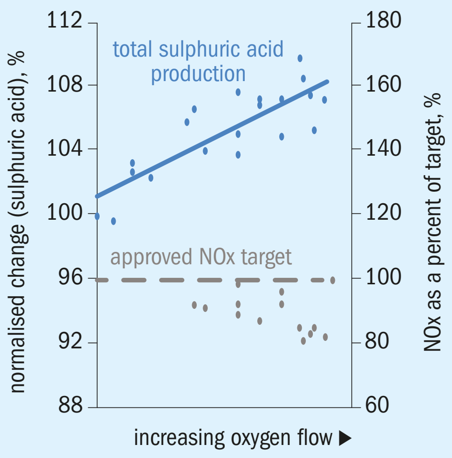
Fig. 4 demonstrates the effect of increasing oxygen flow rate on the NOx mass emission flow rate as the spent acid processing and pure acid production rates increase. While this figure only shows the acid production rate, these are the same operating conditions shown in Fig. 2, where the spent acid processing rate reaches 130% of the baseline. The approved NOx target depicted in the figure represents the NOx mass emission rate that provides the site with a sufficient cushion to be able to operate long-term without approaching its regulatory limit. The test conditions are the same as those shown in Fig. 3 and illustrate the reduction in NOx mass emissions with increasing levels of direct furnace oxygen injection. The results of the testing proved that the SAR unit can operate long-term with moderate levels of oxygen injection and maintain elevated rates for spent acid processing and pure acid production without exceeding the existing NOx limit.

Once the test data was compiled and analysed, there were additional environmental benefits identified because of the increased amounts of oxygen injection. One of the most dramatic of these was the reduction in the amount of energy required to decompose a unit of spent acid as the oxygen flow rate increased. The improvement in the energy efficiency of the enhanced oxygen combustion is caused by the reduction in the amount of ambient nitrogen that accompanies the lower air flow rates. The nitrogen acts as a heat sink on the process, and removing it means that a larger fraction of the heat introduced to the process can go toward spent acid decomposition.

Fig. 5 demonstrates this trend and uses the term "carbon intensity" to represent the energy efficiency improvement with higher oxygen levels. These values were calculated by summing the different sources of heat introduced to the process and dividing by the mass of spent acid processed. This calculation included the reduced amount of heat contained in the preheated combustion air as the air flow rate decreases with increasing oxygen flow. At the higher oxygen injection rates, and as the spent acid processing rate increased by 30%, the carbon intensity (or heat per mass unit of spent acid) decreased by 23%.

In another emission-related observation from system operation, the plant noticed that at a given pure acid production rate, the stack emissions of SO_2 decreased with increasing oxygen flow. In the SAR unit, the SO_2 exits the furnace and is sent to a catalytic converter to be oxidised to SO_3. The converter is highly efficient, but some fraction of the unoxidised SO_2 ends up being emitted from the stack. It is believed that the decrease in the volumetric flow rate through the converter increases the residence time and produces a higher conversion efficiency. The plant has reported that its stack SO_2 emissions have decreased by up to 30% at a fixed acid production rate when oxygen flow is increased. This feature bears further investigation in the future.

Fig 4: NOx emission rate with increasing sulphuric acid production and oxygen addition



Source: Messer

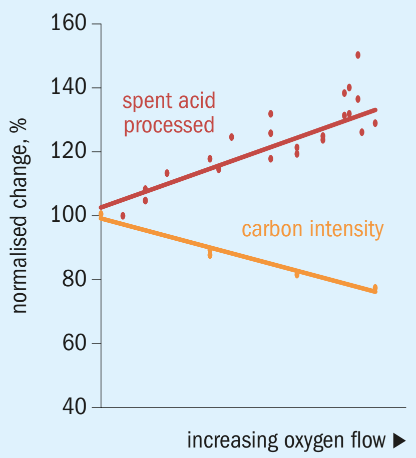
Summary and next steps

A plant desired to increase the capacity of its SAR unit to process spent acid and to make pure spent acid while maintaining its NOx emissions at or below its current levels. A concept was developed to displace some of the combustion air used in the process with pure oxygen to reduce the volumetric flow rate through the furnace at a given spent acid processing and pure acid production rate. The oxygen could either be used to enrich the combustion air or injected directly into the furnace. A process mass and energy balance simulation and a CFD model of the decomposition furnace were developed to determine the impact of introducing oxygen at different rates and locations and to predict the performance improvements and resulting NOx emission rates. Based on the results of the simulations, the team developed an oxygen supply and delivery system designed for the unit.

Testing of the system demonstrated that displacing some of the combustion air with pure oxygen allowed the furnace to process 30% more spent acid while increasing pure sulphuric acid production from 5% to 10%. Due to the ability to reduce the feed of other sulphur-containing feed streams to offset the higher spent acid rates, the economics of this solution were very attractive. The testing showed that oxygen enrichment of the combustion air would cause a significant increase in the NOx emission rate. However, by injecting oxygen directly into the furnace and separate from the burners, the mass emissions of NOx were found to decrease with increasing production rates. As the spent acid processing rate increased by 30% and the acid production increased by 5% to 10%, the NOx decreased by 10% to 15%. The data also indicated that the displacement of air by pure oxygen increased the efficiency of the process and the amount of heat input required to process a unit of spent acid decreased by 23%.

Additional activities are planned for the continued evaluation of this approach, the first of which is the continued operation of the current process at the elevated rate of oxygen injection to confirm that the performance can be maintained. The system has been in operation for over a year and has produced results that are consistent with those obtained during the initial demonstration testing. A plan is being developed to perform additional testing to better assess the impact of oxygen addition upstream of the catalytic converter to improve conversion efficiency and reduce stack SO_2 emissions. It is also hoped that a second SAR unit can be identified to conduct analysis and testing of the oxygen addition to verify that similar performance improvements are achievable and possibly to identify additional benefits of the technology. ■

Fig 5: Reduction in energy input per unit of spent acid processed



Source: Messer

Reference

Stapper B., Studer P. Liu G and Richardson A. (Messer Americas): "Capacity improvement of an existing spent acid decomposition furnace", presented at Sulphur + Sulphuric Acid 2023, New Orleans (Nov 2023).

Energy optimisation in amine sweetening units

Aparna Saiju and **Nishevitha U G** of SLB-MPS explore the concept of energy optimisation using power recovery turbine (PRT) technology in amine sweetening units, focusing on its potential benefits, implementation strategies, and environmental implications.

Energy optimisation is a critical concern in the oil and gas industry because it directly impacts operational efficiency, cost effectiveness, and environmental sustainability. One area in which significant energy savings can be achieved is the amine sweetening process, which is an essential step in natural gas processing for the removal of acid gases like H_2S and CO_2. A chemical solvent, typically monoethanolamine (MEA) or diethanolamine (DEA), is used to absorb acid gases from the sour gas stream, creating a rich amine. The rich amine is then regenerated to release the captured acid gases, and the lean amine is recycled back to the absorber.

One inherent process parameter in the amine sweetening process is the significant pressure difference between the absorber and the regenerator. The absorber operates at high pressures, often ranging from 50 to 100 barg, while the regenerator operates at much lower pressures, typically between 3 and 6 barg. This pressure differential necessitates the use of pressure reduction measures before the rich amine can be sent to the regenerator, resulting in a substantial energy loss.

Traditionally, the reduction of pressure in the amine sweetening process has been achieved through the use of control valves (Fig. 1). These valves regulate the flow of rich amine by throttling it, thereby decreasing the pressure, which dissipates the fluid's energy. A lean amine pump is used to increase the pressure and convey the regenerated lean amine back to the absorber.

The role of power recovery turbines

To address this energy loss, the concept of using power recovery turbines has gained attention. PRT technology offers a more sustainable and economically viable solution for energy optimisation in amine sweetening units.

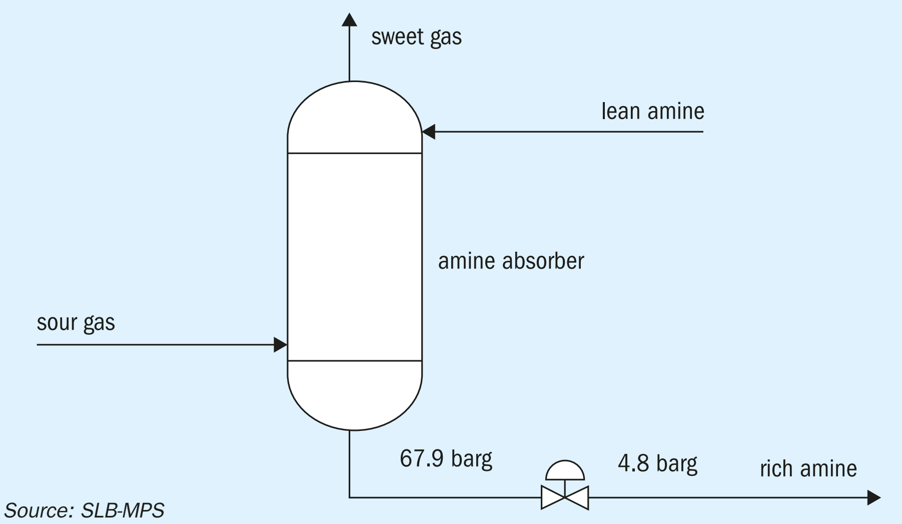
The PRT is designed to capture energy that would otherwise be released during pressure reductions and convert it into useful mechanical energy. This recovered energy can be used to reduce the power consumption of various equipment within the unit, such as pumps and compressors, thereby enhancing overall process efficiency.

Implementing PRTs in amine units

The application of PRTs in amine sweetening units (Fig. 2) involves several key components and operational stages:

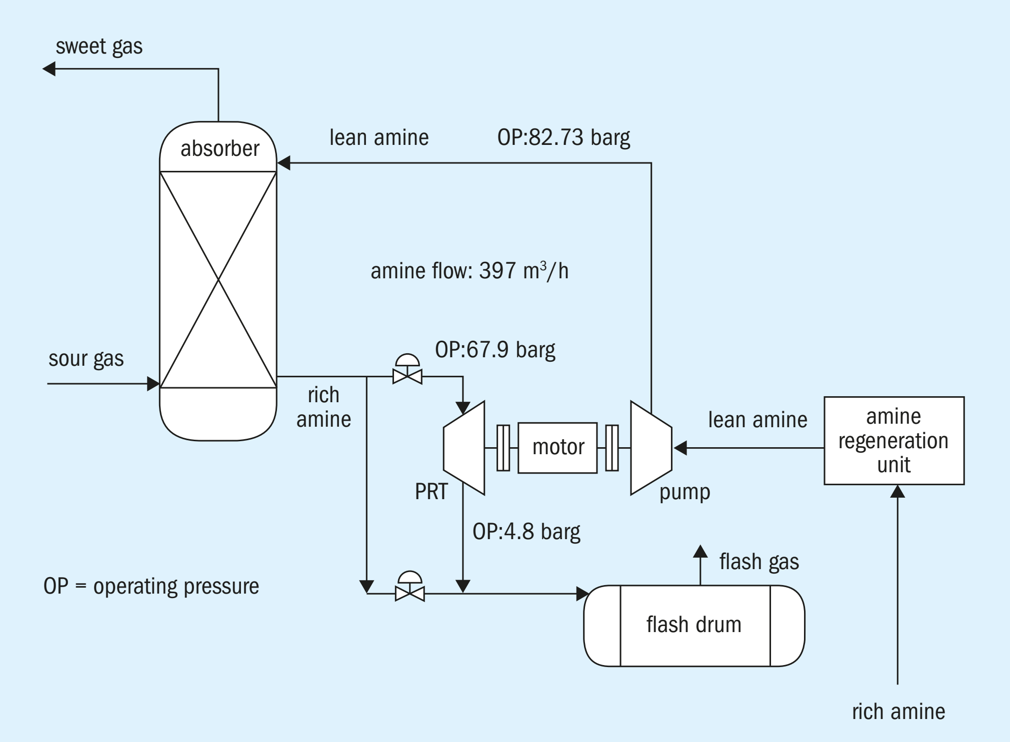
- **Rich amine inlet**: The rich amine, which is saturated with absorbed CO_2 and H_2S, enters the PRT system from the absorber. This rich amine contains a significant amount of potential energy as a result of its high pressure.
- **PRT operation**: The PRT, which is a specially designed turbine, is positioned to receive the high-pressure rich amine. As the rich amine flows through the PRT, it drives the turbine blades. This enables the PRT to capture the energy that would otherwise be lost during the pressure reduction.

Fig 1: **Pressure reduction via control valves in amine sweetening.**



Source: SLB-MPS

Fig 2: **Application of PRT technology in an amine sweetening unit.**



Source: SLB-MPS

- **Mechanical coupling**: The PRT is mechanically coupled to the equipment that requires power, typically a motor driving a lean amine circulation pump. This coupling enables the energy captured by the PRT to be directly used to offset the power requirements of the equipment.
- **Power generation**: As the PRT spins, it generates mechanical energy that can be converted into electrical power by means of a generator. This electrical power can be used internally within the amine sweetening unit or fed back into the facility's power grid, reducing energy consumption and operational costs.

Carbon footprint reduction

The integration of PRTs in amine sweetening units offers a multifaceted approach to sustainability. Because the energy produced using PRTs can be used to reduce the power consumption, the PRTs can be instrumental in reducing Scope 2 emissions and help contribute to the industry's sustainability goals. The decreased use of energy generated from fossil fuels reduces the emission of greenhouse gases, including CO_2, which is a critical step toward mitigating climate change.

PRTs significantly enhance energy efficiency by recovering and reusing energy that would otherwise be lost, reducing the need for additional power generation, which often relies on fossil fuels, and thereby lowering carbon emissions. Energy optimisation achieved as a result of PRT integration results in cost savings because decreased energy consumption reduces operational expenses.

Case study quantification

The following case study, which is based on an amine sweetening unit with a capacity of 397 m³/h for treating 60 MMscf/d of sour gas, illustrates the energy reduction potential of PRT integration. The critical parameters of the case study were:

- Circulation rate of lean amine: 397 m³/h
- Rich amine pressure at contactor outlet: 67.9 barg
- Density of rich amine at absorber column outlet: 1,037 kg/m³

Considering there is a 4.8 barg operating pressure requirement at the rich amine flash drum, the available differential head for power generation is 622 m after considering a 10% frictional loss.

The power generated using this available head is calculated as $[(397\ m^3/h \times 1{,}037\ kg/m^3)/3{,}600$ seconds per hour $\times\ 9.8\ m/s^2 \times 622\ m] = 697$ kW

For this case study, considering the efficiency of PRT as 75%, the power recovered by means of the PRT - which can be integrated with the motor of the lean amine pump per the schematic shown in Fig. 2 – is 522 kW.

Assuming 0.46 kg of CO_2 equivalent (CO_2e) per kilowatt-hour as the global electric emissions factor, in this case study, implementing a PRT reduces the carbon footprint of amine unit by 1,921 tonnes of CO_2e per year.

Payback analysis

A payback analysis was performed to assess the financial feasibility of a PRT installation. Table 1 presents the payback analysis for the aforementioned case study, focusing on the generation of 697 kW. The savings (in USD) were calculated on the basis of 8,000 hours of annual operation. The listed price of the PRT represents the average value that was obtained by comparing prices from various PRT vendors. The results indicate that the PRT system should recover its cost in less than 1.1 years. This relatively short payback period is generally deemed acceptable by most customers.

Modes of implementation

Revamping an existing facility

One of the key advantages of this technology is that a PRT can be installed in an existing amine sweetening unit. If there is available footprint, the motor of lean amine circulation pumps can be coupled with the PRT to recover power, although

Table 1: **PRT payback analysis**

Volumetric flow, m³/h	397
Differential pressure, bar	63
Efficiency, %	75
Power recovered with PRT, kW	697
Average electricity cost in US, USD per kWh	0.0845
Annual energy savings, USD per year	471,000
Capital cost, USD	509,000
ROI (capital cost), years	1.1

Source: SLB-MPS

the existing motor may need to be modified or replaced. In other instances, the PRT can be used to directly drive a generator feeding the power grid.

Adding a PRT during project implementation

A detailed study of the feasibility of implementing a PRT in an amine sweetening unit for various capacities was carried out as shown in Table 2. It was observed that PRT implementation is not feasible for low flow rates.

Table 2: **Recovered power from PRT with different flows and differential pressures of plant data**

Amine flow rate, m^3/h	Available differential pressure, bar	Recovered power from PRT, kW	CO_2 footprint reduction, tonnes CO_2e per year
90.85	74.75	102.4	454.3
397	63	527.4	2,352
204.4	35.9	157.8	700.3
306.6	60.47	411.6	1830.3

Source: SLB-MPS

Challenges in PRT implementation

The implementation of PRT in amine units can pose the following challenges:

- **Seal quality**: A seal leak in the PRT can result in H_2S exposure because of the rich amine. The risk can be mitigated by providing double seal & Seal Plan 53B.
- **Footprint**: Implementation in offshore platform can become a major challenge considering the footprint limitation.
- **Operational issues**: When the flow is inadequate, the PRT can overload the motor. To prevent this, a one-way clutch is required. In addition, when the PRT is used to directly drive a generator, precautions must be taken to ensure mechanical reliability in the event of a power failure.

Conclusion

The integration of PRTs in amine sweetening units represents a pivotal step toward achieving sustainable and efficient energy use within the oil and gas sector. By transforming energy that would otherwise be wasted into a valuable resource, PRTs enhance energy efficiency, reduce operational costs, and mitigate carbon emissions. The case study quantification clearly demonstrates the substantial energy recovery potential that could be achieved through PRT integration, enhancing the sustainability and economic viability of amine sweetening units.

Digitalised sulphur recovery plants for greater plant efficiency

The pursuit of operational excellence requires continuous process monitoring, together with qualified analysis of the collected data. The Digital Process Monitor (DPM) provides a process digital twin which consists of an accurate process plant model that incorporates the licensor's knowledge and expertise in sulphur recovery technology, thereby providing continuous insights into plant performance. This article provides an overview of the DPM features focusing on the related benefits in terms of overall operational improvements and plant efficiency for the sulphur recovery unit.

E. Pasqualon (MAIRE) and M. Antonelli, D. Boni, A. Costantini, S. Romangnuolo (NextChem)

The digital economy is becoming a major focus for many businesses, from conventional hydrocarbon processing to the domain of green chemistry.

Operating a sulphur recovery unit (SRU) is always challenging, and good management translates into improved safety and reliability. But sometimes operators can be unaware, and this becomes a critical factor potentially leading to loss of production, equipment damage and tarnished reputation; therefore, by adopting digital tools and properly incorporating the know-how of the licensors, this pain point can be resolved as well as reducing plant operating expenses (opex) by increasing margins for the plant owner.

In addition, the contribution of digital tools in assisting opex reduction means that the initial investment required for their implementation, as well as the recurring annual cost to maintain them, can be recouped within the first year of operation. Therefore, a payback time of less than one year implies that the annual opex savings are ongoing benefits that are unlocked over time by digital technologies for the plant owner.

The Digital Process Monitor (DPM)

DPM architecture overview

The DPM is a cloud-based solution co-developed by a series of MAIRE group's companies, specifically NextChem, Stamicarbon, Tecnimont, and KT-Kinetics Technology affiliates of MAIRE group.

MAIRE is a leading technology and engineering group that develops and implements innovative solutions to enable the energy transition. Through its subsidiaries, the group offers sustainable technology solutions and integrated E&C solutions in nitrogen fertilizers, hydrogen, circular carbon, fuels, chemicals, and polymers.

The DPM is based on a first-principles plant model where all of the most important phenomena are rigorously simulated leveraging on unique knowhow as licensor, thereby guaranteeing the highest level of accuracy and adherence between the model response and the behaviour actually observed in reality.

The model is fed with data derived from the plant's distributed control system (DCS) through a unidirectional data flow. The plant model unlocks valuable information that a DCS alone cannot provide, and with both automated procedures and the licensor's intervention, it can formulate recommendations for board operators and send them through dedicated user interfaces to enhance the plant's performance.

It will then be the board operations' duty to implement the recommendations provided by the licensor through the DPM, by modifying process variables through the DCS to effectively enhance performance improvements.

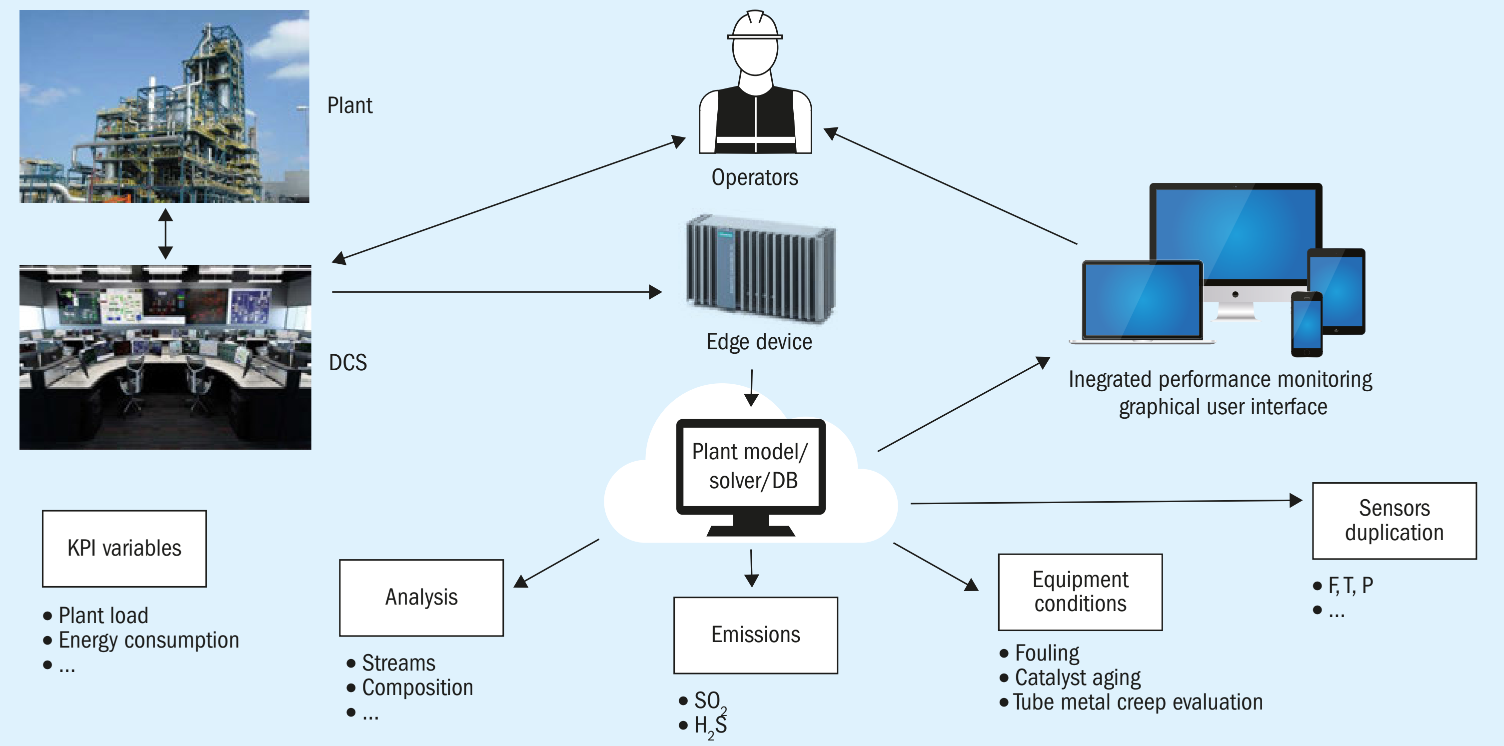
DPM data flow

Input data (online data from the plant's DCS and offline data derived by measurement campaigns) are acquired by the DPM. A data validation algorithm verifies the quality of raw input data and excludes unreliable ones. Validated data then feed the process model by generating simulated data and soft sensors, which consist of new process variables calculated starting from the DCS data that has been properly manipulated.

The quality of online measured operational data has been addressed by introducing a data reconciliation algorithm to resolve data inconsistencies and improve data reliability.

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 1: **DPM architecture overview**



Source: Maire

Following reconciliation, data analysis takes place by leveraging on the comparison between process validated data derived from the DCS and reconciled process data calculated by the process model itself; the tool, with the support of licensor specialists, is capable of generating advice to correctly operate the plant as near as possible to the optimum design conditions.

Fig. 2 represents a schematic architecture of the DPM dataflow as implemented in the software.

Licensor modelling

As already stated, the DPM leverages on a digital replica of the SRU using a simulation engine.

The licensor is the most expert modeller of its own licensed technologies due to the combination of a strong theoretical knowledge and operating SRU feedback.

In addition, licensor's models include special unit operation blocks for proprietary equipment, customised for licensor design and not available in commercial simulation packages. These customised blocks include the:

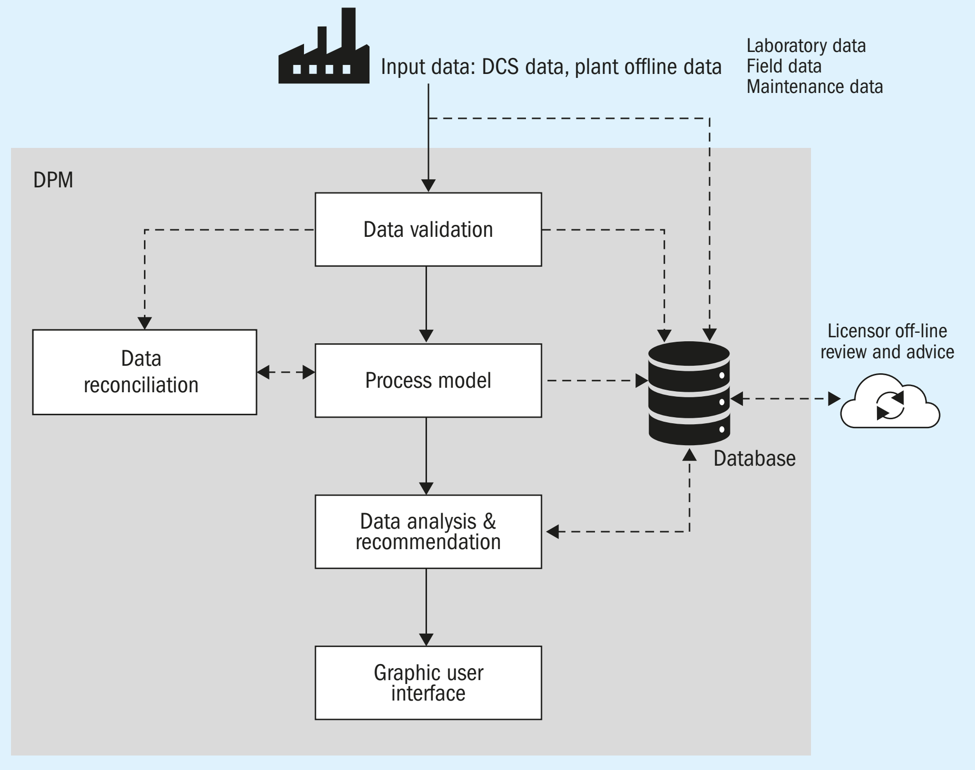
- thermal reactor (including NH_3 destruction models);
- Claus waste heat boiler;
- sulphur condensers.

In this way proprietary equipment is precisely reproduced in the digital replica by leveraging on the licensor's consolidated thermodynamic models, providing the most reliable prediction of the SRU's behaviour.

Data reconciliation

Data reconciliation resolves the possible inconsistency of field data, providing an automatic solution to a problem that until now has been solved manually by the licensor's engineers.

Fig 2: **DPM dataflow**



Source: Maire

Normally, the quality of online measured operational data is not satisfactory for the evaluation of the plant's performance, because they are never error free, and even careful installation and maintenance of the hardware cannot fully eliminate this problem. In fact, after collection of plant data, engineers always conduct an analysis to make raw data consistent (for example, from a heat and material balance perspective) so they can conduct a reliable assessment of plant behaviour.

Data reconciliation is a data preprocessing technique which can improve the accuracy of measured data through process modelling and optimisation, identifying potential anomalies in the input data. In other words, licensor data analysis is provided to the plant owner as a ready-to-use tool.

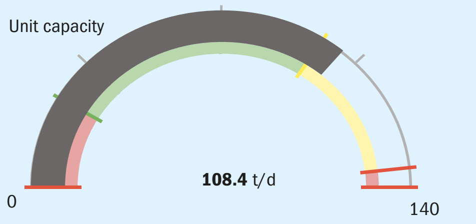
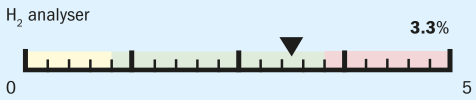
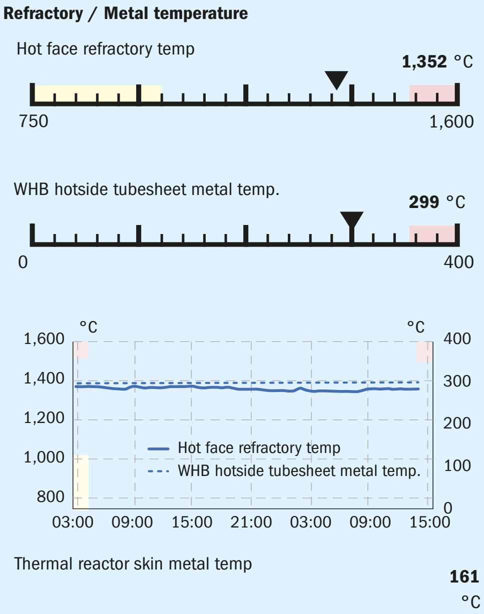
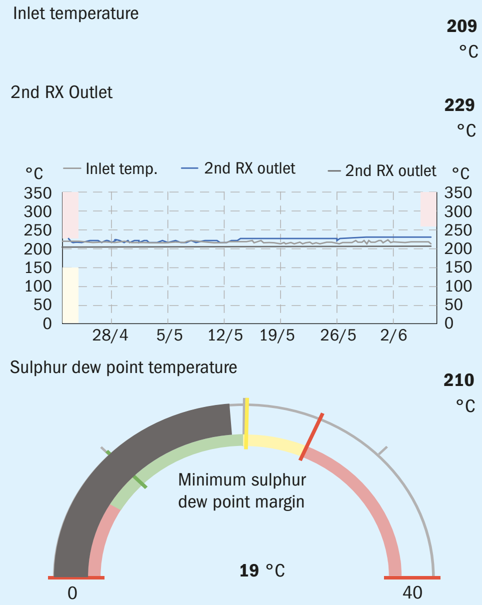
On the theoretical side, data reconciliation is summarised as a general optimisation problem, solving an objective function. The objective function is a weighted sum of the relative differences between selected reconciled process data and the corresponding DCS process measured data as indicated by the formula shown below (equation 1):

$$\phi_{MIN} = \sum_{i=1}^{N} W_i \left(\frac{X_{DCS\_i} - X_{CALC\_i}}{X_{DCS\_i}}\right)^2 \qquad (1)$$

Where:
N = number of variables selected for the objective function
X_{DCS} = DCS data (measured validated data)
X_{CALC} = data reconciled calculated by process simulator
W_i = weight factor chosen by the licensor to reflect the importance of each process data considered in the objective function.

Minimisation of the objective function is done by manipulating some of the variables involved in the reconciliation (typically coinciding with the process data controlled by the DCS). The choice of the manipulated variables, among all the DCS recorded data, is made by the licensor. The variables are manipulated inside a certain interval (standard deviation) which is also implemented by licensor according to the type of process data. The mathematical problem is solved through the Bobyqa algorithm, which consists of a variation of the Powell method for finding a local minimum of a function.

Table 1: **Examples SRU KPI and soft sensors available on the DPM dashboard**

Parameter	Parameter typology	Dashboard visualisation
Total sulphur production	KPI	
H_2 at quench overhead	KPI	
Overall sulphur recovery efficiency	KPI	
Predicted thermal reactor refractory and metal temperature	Soft sensors	
2nd Claus reactor temperature monitoring	Soft sensors	

The numerical solver is independent of the simulation engine used, meaning that the tool can even eventually be used for the reconciliation of the processes with different proprietary sulphur recovery technology. A schematic representation of the reconciliation data flow is reported in Fig. 3.

DPM dashboard

The DPM dashboards are the main graphic user interface and are designed by the licensor to provide operators with a quick and comprehensive overview of plant behaviour. Literally, DPM dashboards provide plant owners with a handy overview of plant operation in their pocket at all times: dashboards are designed to be visible on multiple devices such as laptops, tablets, or smartphones. Data reported on dashboards are not only DCS data, but also helpful operating parameters (soft sensors) that cannot be derived directly from the DCS but are continuously calculated by the DPM model. Traditionally, these key parameters have not been available to operators for their immediate use, as they derive from an analysis of DCS data which can take hours to days, delaying any necessary remedial action. The DPM's goal is to automatise this process, creating a live report of plant operation, minimising the time between diagnosis and remedies in the event of an upset or deviation from optimum running conditions.

Table 1 shows some snapshots of prototype dashboards for the SRU, with the aim of giving a comprehensive overview of DPM dashboard functionalities.

The content of dashboards is intended to be customised by the licensor to fit with specific requirements of plant owners. However, in principle, dashboards are designed to be composed of multiple sections:

- a main board giving an overview of plant operation / production, showing feedstock and product quantity and quality;
- dedicated boards for each plant section, showing the main operating parameters and the key factors that will be closely monitored;
- dedicated boards resuming KPI of the plant and showing possible savings.

Case study of a sulphur recovery unit

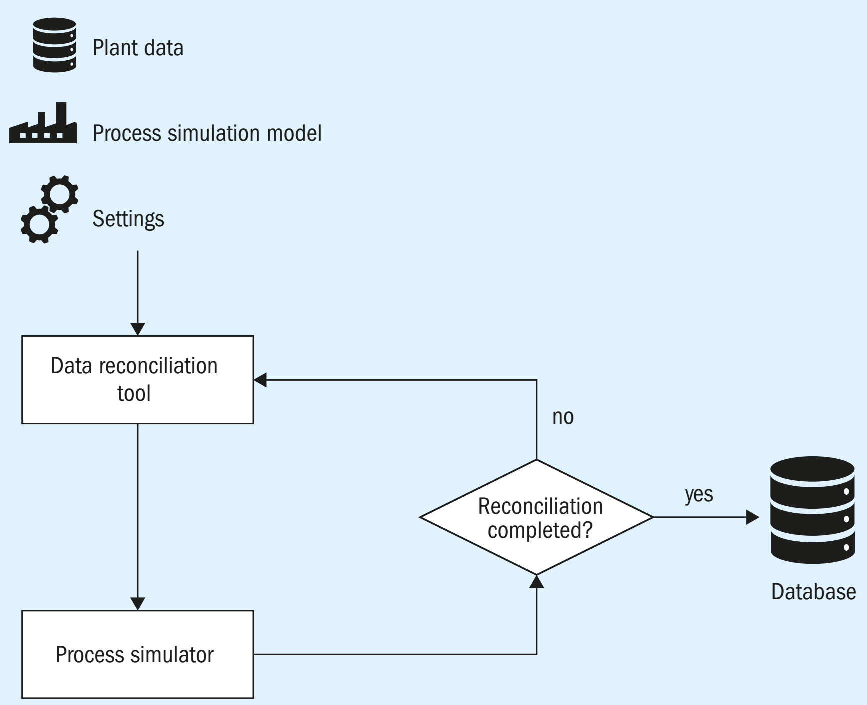
Methodology

A case study has been conducted on an existing SRU with a capacity of 190 t/d of recovered sulphur located in Europe.

The SRU is composed of:

- two identical Claus trains,
- one TGT train with an external amine regeneration unit;
- one incinerator section equipped with waste heat recovery composed of steam production and steam superheating.

Fig 3: **Data flow of reconciliation tool**



Source: Maire

Amine regeneration, being part of another unit, was not considered part of the case study.

A whole year set of hourly plant DCS data was made available by the plant. Starting from raw data, a data selection was performed to identify the following representative cases:

- plant fully aligned (2 Claus trains + TGTU + incinerator)
- stack emissions not out of spec.;
- steam superheater online.

The selected set of data were averaged monthly. The following KPIs were chosen to identify a representative case for each month:

- fuel gas consumption at incinerator;
- hydrogen measured at quench tower outlet
- Claus efficiency.

The timestamp which represented the closer scenario to the average one based on the KPIs listed above was chosen as representative case for the month.

All representative cases were then reconciled to minimise the errors of DCS data, thus becoming the benchmark for the optimisation study.

Opex saving estimation

For each month, a representative case was optimised by the licensor within the SRU digital replica according to the following criteria:

- temperature of incinerator chamber equal to 630°C, minimum for achievement of target emissions;
- hydrogen at quench tower top lowered at 3.5 vol-%, which is an acceptable value for complete conversion of sulphur compounds in the hydrogenation reactor;
- second Claus reactor inlet gas temperature of 200°C, which was found compatible with the sulphur dew point of the tail gas predicted by the DPM;
- hydrogenation reactor inlet temperature of 220°C minimum, which is an acceptable inlet temperature for a low temperature hydrogenation catalyst.

All the benchmarks and the optimised cases were averaged to create an average utility consumption summary, in order to evaluate eventual savings in terms of opex. The utility consumption of the averaged benchmark and optimised cases are reported in Table 2.

Table 2: Utility consumption in the SRU case study

Utility	Reconciled value	Optimised value
Fuel gas, kg/h	296	307
Boiler feed water, t/h	27.9	27.3
Cooling water, t/h	482	482
Export LP steam, kg/h	7,614	7,031
Export MP steam, kg/h	0	0
Export HP steam, kg/h	17,258	17,509
H_2, kg/h	24	6
Electrical power, kWh	782	530

Source: Maire

Table 3: Utility costs for European area under examination for the SRU case study

Utility	Unit price
Fuel gas, €/kg	0.18
Boiler feed water, €/t	0.00
Cooling water, €/t	0.00
LP steam, €/kg	0.012
MP steam, €/kg	0.00
HP steam, €/kg	0.019
H_2, €/kg	1.5
Electrical power, €/kWh	0.093

Source: Maire

The utility costs used in the case study are summarised in Table 3.

The opex savings evaluation was based upon 8,600 hours of plant operation per year.

The results of the case study led to an estimated saving on opex of up to €385,000 per year by implementing the synergy obtainable from the DPM and licensor optimisation.

Carbon footprint reduction

The DPM also contributes to reducing the carbon footprint of SRUs since it allows optimisation of:

- the consumption of fuel gas and hydrogen;
- the consumption of electricity;
- the steam exported at various pressure levels.

Using the case study above, the carbon footprint reduction was calculated according to the following criteria and reasonable simplifications:

- 8,600 yearly operating hours
- the carbon footprint is calculated by assigning equivalent emissions factors only for the electricity and fuel consumptions, having all the other utilities optimised a negligible impact on the CO_2 equivalent emission
- the following CO_2 equivalent emission factors are derived from "*2BS-PRO-03 – Methodology for the calculation of GHG emissions – version 1.9*":
  - 127.65 gCO_{2eq}/MJ for electricity
  - 67.59 gCO_{2eq}/MJ for natural gas and fuel gas

The results of the case study led to ~18% reduction of GHG emissions equivalent to 2,300 t/y of CO_{2eq}. Considering a hypothetical carbon tax of €30 per ton, savings add up to €69,000 per year.

Conclusions

Using the DPM unlocks several advantages as far as reliability and improved plant operation are concerned.

Continuous monitoring gives an improved overview of several features for SRU plants, including:

- critical transient events;
- combustion anomalies;
- hydraulic profile;
- soft sensors representing unmeasured values.

Both short and long-term benefits from using the DPM have been identified. Examples of short-term benefits are:

- identification and analysis of critical operation, avoiding prolonging such operation and preventing possible mechanical damage, excessive utility consumption and minimising environmental impact;
- the monitoring of combustion anomalies, maximising the prevention of undesired breach of emission limits or potential contaminants breakthrough, such as ammonia from the Claus thermal reactor;
- guidance for field instruments recalibration thanks to DPM outcomes improving overall plant reliability.

Long term benefits are listed below:

- monitoring of the catalyst behaviour, helping to reach an optimised catalyst operation, leading to improved performance, lower polluting emissions, early detection of poisoning and catalyst ageing with consequent extension of catalyst life and opex savings;
- monitoring of hydraulic profile, providing an early diagnosis of any fouling or soot deposition happening in the plant, thus preventing plant operation disruption due to high pressure losses, or allowing a more optimised planning of turnarounds.

The above lists provide examples of just some of the numerous benefits which a more digitally enhanced approach can bring to the energy sector. As is well known, the energy sector is a very conservative business segment, but today there are two game-changers that can dramatically accelerate the changes already occurring in adjacent sectors such as insurance, banking, retail, etc.

Digital transformation and the energy transition are two sides of the same coin, because the goal of decarbonising existing and new industrial complexes can be effectively achieved only by leveraging on digitalisation.

Going forward, MAIRE will continue to develop and improve its newly created tools, which are part of MAIRE's NextPlant digital platform, for managing the operational challenges in low carbon chemistry and the hydrocarbon processing arena.

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

Carbon capture in the sulphur value chain

Readers of *Sulphur* magazine have always been at the forefront of operating, designing, researching, and troubleshooting process units in the sulphur value chain. However, more recently, with the emergence of net zero initiatives by international conventions and governments (e.g. the Paris agreement), the push for decarbonisation in our industry has been on the rise. **Ganank Srivastava** of Bryan Research & Engineering takes a look at the bigger picture and examines ways to reduce carbon footprint in sour gas facilities.

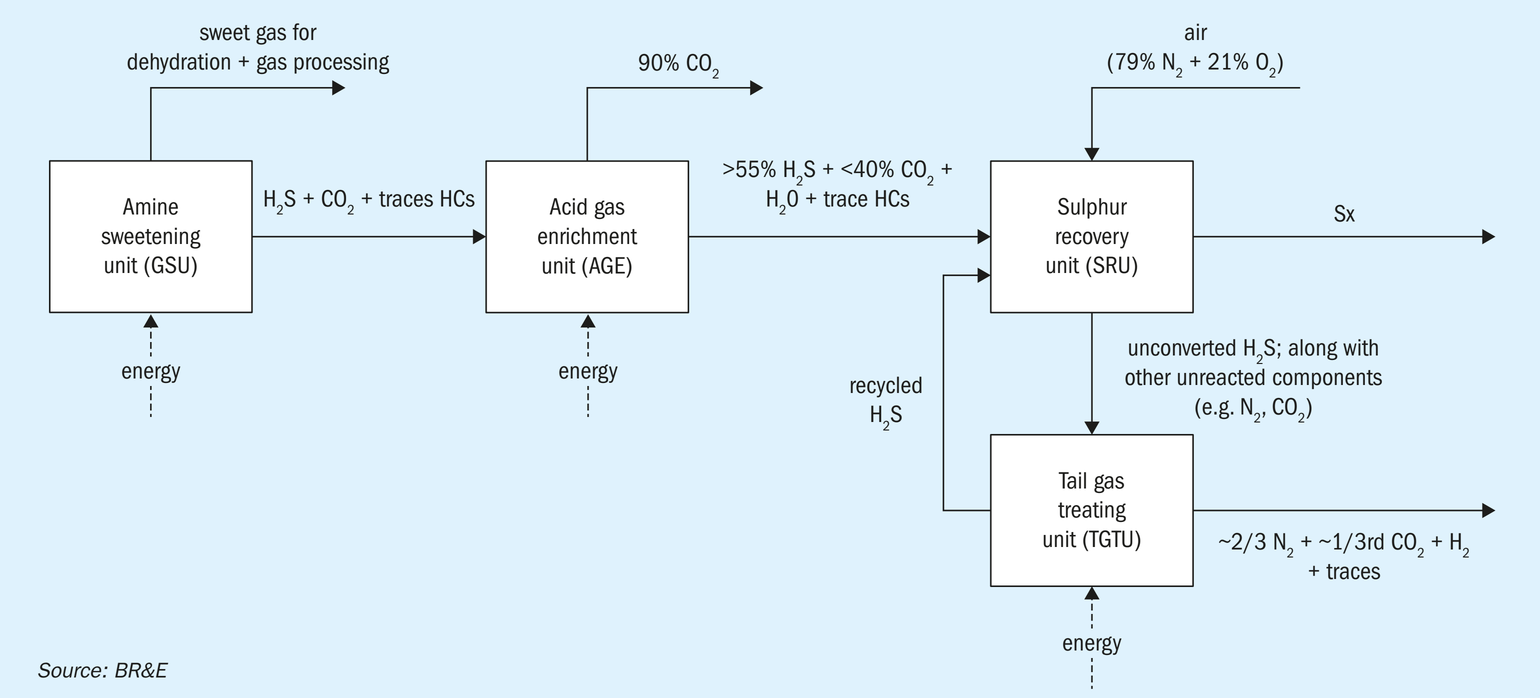
Conventional sour gas plant process scheme

The treatment section is the heart of any sour gas processing facility. Usually, the hydrocarbons entering the plant travel through the following process units to prepare contaminant free natural gas (C_1) for safe transportation and consumption: gas sweetening/GSU (to remove acidic H_2S, CO_2) → gas dehydration/GDU (to remove H_2O) → turboexpander/DeC$_1$ (to remove NGL). Responsible and compliant energy companies usually further invest in a sulphur recovery unit (SRU) that safely disposes of the acidic gaseous contaminants removed in the amine sweetening section (by converting harmful H_2S to marketable sulphur, Sx). The front-end of a SRU also involves a burning step, where a portion of the acid gases react with O_2 from air to produce SO_2; which serves as a key reactant for subsequent sulphur production. Due to process inefficiencies, trace hydrocarbons making their way to SRUs, will be converted to unavoidable CO_2 during this step too.

It is important to keep in mind that the CO_2 (from either the acid gas mix or combustion step) and N_2 (from air) do not participate in or contribute towards the sulphur recovery reactions of H_2S → Sx. They are both inerts in the process that reduce efficiency and simply occupy volume.

To enhance the long-term cost benefits of such units, some operators therefore modify the aforementioned scheme with two additional units: an acid gas enrichment unit (to purify the H_2S content in the acid gas mixture entering the sulphur recovery unit) and tail gas treating units (to recycle unconverted H_2S from the sulphur recovery unit back to the beginning of the unit). The final block flow diagram of a representative facility is shown in Fig. 1.

Fig 1: **Conventional sour gas plant**



Source: BR&E

Tracking key CO_2 exit points – decarbonisation opportunities

The above process scheme shows us that CO_2 (our key-component for this analysis), has three key exit points: the AGE vent line, the TGT vent line, and all the emissions generated from heat sources providing energy to run the plant. Their rough operating conditions can be summarised by Table 1 using representative facilities.

Table 1: **Summary of CO_2 exit points in a sour gas facility**

Source	CO_2 (mol%)	Operating pressure (psig)	Operating temperature (°F)
AGE vent	>85%	~10	120
TGT vent	<40%	~7	120
Heat sources	<7.5%	~1	1,200 (before heat recovery)

The table gives us three straight-forward conclusions:

- Strictly from a partial pressure and operating conditions viewpoint, heat sources will be the most capex and opex heavy opportunity when it comes to effectively capturing CO_2. However, this might be the most prevalent source of carbon emissions from oil and gas facilities.
- The AGE vent is a rich CO_2 line that needs minimal investment to recover.
- The TGT vent is an opportunity that has a relatively rich CO_2 concentration and can be further optimised to enhance cost benefits for carbon capture.

Modifications and technologies to enhance cost-effectiveness of carbon capture

Claus Oxygen Enhanced Process Expansion (COPE) is a SRU technology that is gaining a lot of traction in recent times. It is a process improvement that not only reduces the capital/size footprint of a sulphur plant but also opens the door for cost-effective carbon capture. This is achieved by using enriched or pure O_2 (80 to 100 %) instead of air in the front-end of an SRU during the acid gas burning step. This completely removes inert N_2 in the sulphur recovery section of the value chain. A ProMax® process simulation model demonstrates that this can reduce actual volumes of an SRU by almost 60% (see Fig. 2). This would mean that one O_2-enriched SRU is roughly equivalent to two air-based SRUs in terms of overall performance (potentially even overcompensating the opex to produce pure O_2).

The benefits of having no N_2 in the process (see Fig. 3) cascades over and increases the CO_2 concentration in the TGT vent line from <40 mol-% to beyond >75 mol-% (making the operating conditions of this stream similar to an AGE vent line). This effectively reduces the scope of carbon capture opportunities in the sour gas value chain to two - heat sources (with <7.5 mol-% CO_2, 1 psig) and TGT/AGE vent lines (with >75 mol-% CO_2, 7.5 psig).

Available carbon capture technologies in the market today can be broadly categorised into three types: chemical solvents (e.g., amines), physical solvents (e.g., DEPG) and non-solvent options (e.g., cryogenic cold flashing). In terms of published reports in the literature on technology maturation, successfully implemented CO_2 capture plants, and operational/financial efficiency, there definitely seems to be a tilt in favour towards solvent-based capture systems.

Several different solvents are available for capturing CO_2. The diagram in Fig. 4, extracted from Bryan Research & Engineering's BRE231 training manual, summarises general guidelines for best solvent selection.

One can see that the two opportunities discussed in this article lie below the 10-psi mark on the y-axis where amines will be the best choice.

MEA has long been considered as the industry baseline generic amine solvent for low-pressure carbon capture systems. Being a primary and therefore aggressive solvent, it is known to effectively extract CO_2 from a mixture of other gases even at extremely low partial pressures. However, the heat of reaction between MEA and the acid gases is large which leads to larger energy requirements for solvent regeneration.

In comparison, the AMP + PZ blend, is starting to create a lot of noise for the right reasons as a potential new baseline. AMP, a sterically hindered yet highly reactive primary amine, acts as the CO_2 "holder";

Fig 2: **Actual volumetric benefits of O_2 enhanced SRUs**

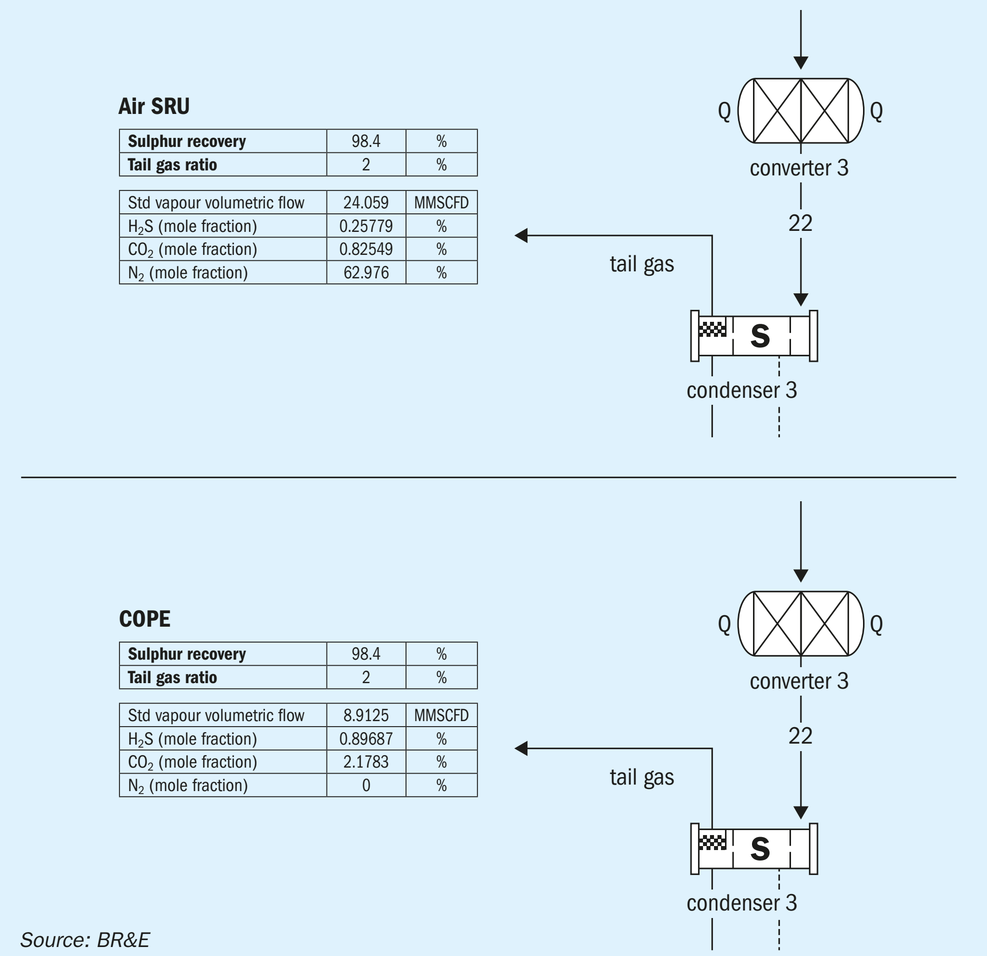


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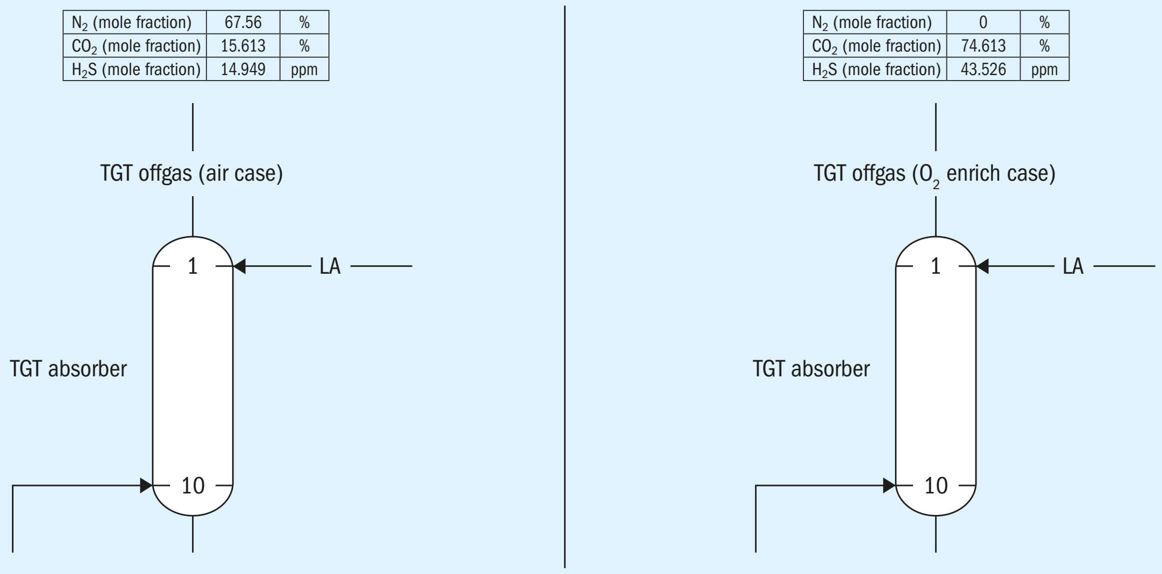
Fig 3: **Enhancing cost benefit of CO_2 capture in TGT exit (using O_2 enhanced SRUs)**



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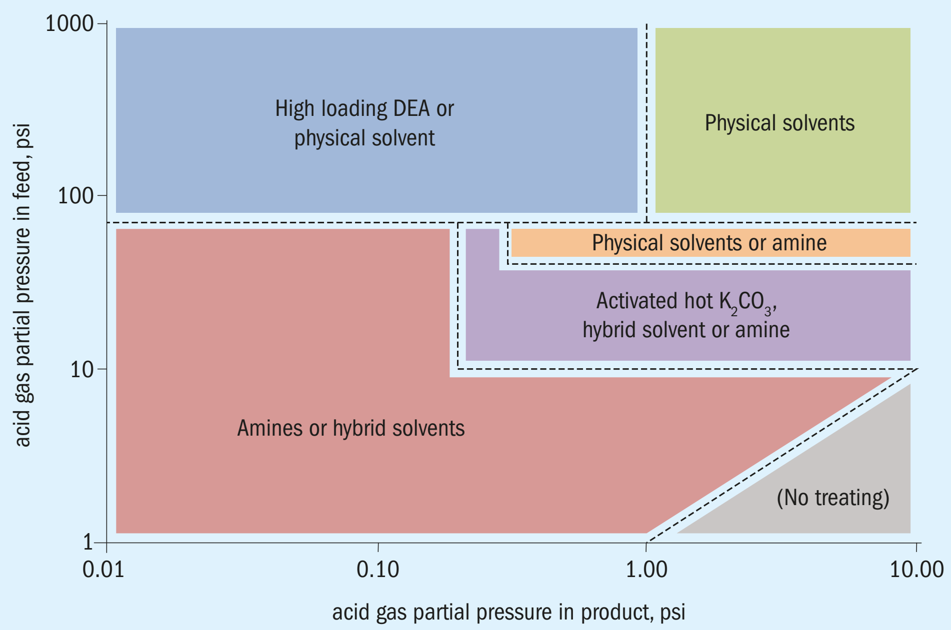
while PZ, an amine activator, acts as the CO_2 "grabber". Running a ProMax® process simulation model comparing AMP + PZ versus MEA for capturing >95% CO_2 from a LP stream (representative of a heat source opportunity) showcases energy savings of ~50% (see Fig. 5).

Another thing to keep in mind is the formation of degradation products in the presence of contaminants like O_2 and SOx. These are probably contaminants in the flue gas along with CO_2, when fuel is burnt for generating energy. MEA, because of its aggressive and highly reactive nature tends to have the highest rate of degradation product formation. On the contrary, AMP is known to have a slower rate making it a slightly more viable option when activated with PZ.

It is noteworthy to point out that for decarbonisation opportunities on AGE/TGT exits, where CO_2 is slightly more concentrated (>75%) and there is no presence of O_2 or SO_2, reactive primary solvent options like MEA or AMP/PZ may not be required. More stable, popular, easily monitorable options like aMDEA (MDEA + PZ) might also work. Even though MDEA is a tertiary and less aggressive solvent, the higher partial pressure of CO_2 in these opportunities can make it a potential candidate, especially when PZ is added in the range of 5-7 wt-%. As one can see from Fig. 6, MDEA + PZ can still achieve around 90% CO_2 recovery when stacked up against AMP+PZ for an AGE/TGT exit opportunity using the exact same flow rate and reboiler duty.

Cold flash or cryogenic systems might also be a strong candidate to recover CO_2 from such concentrated streams (into pure CO_2 liquid); though sufficient power may be required to compress the gas to increase its dew point for cost-effective condensation, while care must also be taken to dehydrate the gas to avoid ice formation during cooling. A thorough techno-commercial analysis of cold flash technology was not carried out for the purpose of this article as it was qualified as a non-mature and expensive alternative to solvent based options. However, licensors can be approached to evaluate this opportunity at rich CO_2 exit lines.

Fig 4: **Physical vs chemical solvent selection for acid gas removal**



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Additional key considerations

While designing carbon capture units, it is also crucial to keep in mind some additional considerations, specifically with regards to mass transfer efficiency. At low pressures, it is imperative that the hardware selected provides the optimum mass transfer of CO_2 from the vapour phase to the aqueous amine. As can be seen from a the representative case in Fig. 7 for flue gas carbon capture at atmospheric pressure, structured packings provide better performance compared to trays.

Another design consideration to keep in mind is the temperature and contaminants

Fig 5: **Opex of AMP/PZ vs MEA (wrt solvent regeneration)**

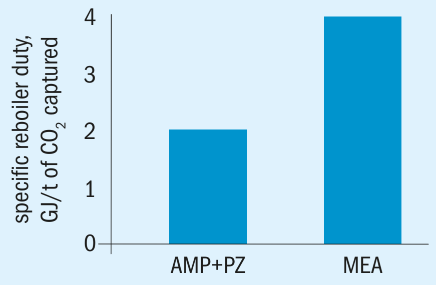

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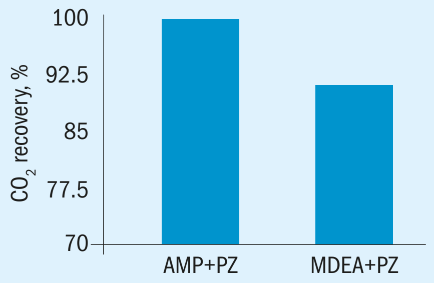
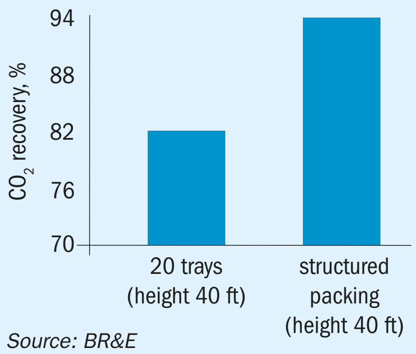
Fig 6: **Efficiency comparison of aMDEA vs aAMP (at same conditions)**



CO_2 recovery using same solvent flow & reboiler duty at AGE/TGT exits, with >70% CO_2 in feed

Source: BR&E

Fig 7: **Efficiency comparison of packed vs trayed columns**



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present in the CO_2 exit line that is routed for removal. CO_2-amine reactions are exothermic in nature and therefore extremely hot lines can disturb this equilibrium in an unfavourable direction. In hot flue gas scenarios, it is therefore critical to install a direct contact cooling tower to bring the temperature of the gas closer to ambient conditions before sending it to an amine-based carbon capture unit.

Contaminants in the feed can also render an amine unit to fail over time. High amounts of SO_2 in feeds (even in ppm amounts) can result in the formation of non-regenerable heat stable sulphites over time making the amine solvent ineffective by being tied up as a salt. A remedy for this is to add caustic wash, saltwater wash, or plain water as possible pretreatment options along with the DCC loop.

Fig. 8 shows a complete process flow diagram of a proposed carbon capture facility.

Conclusions

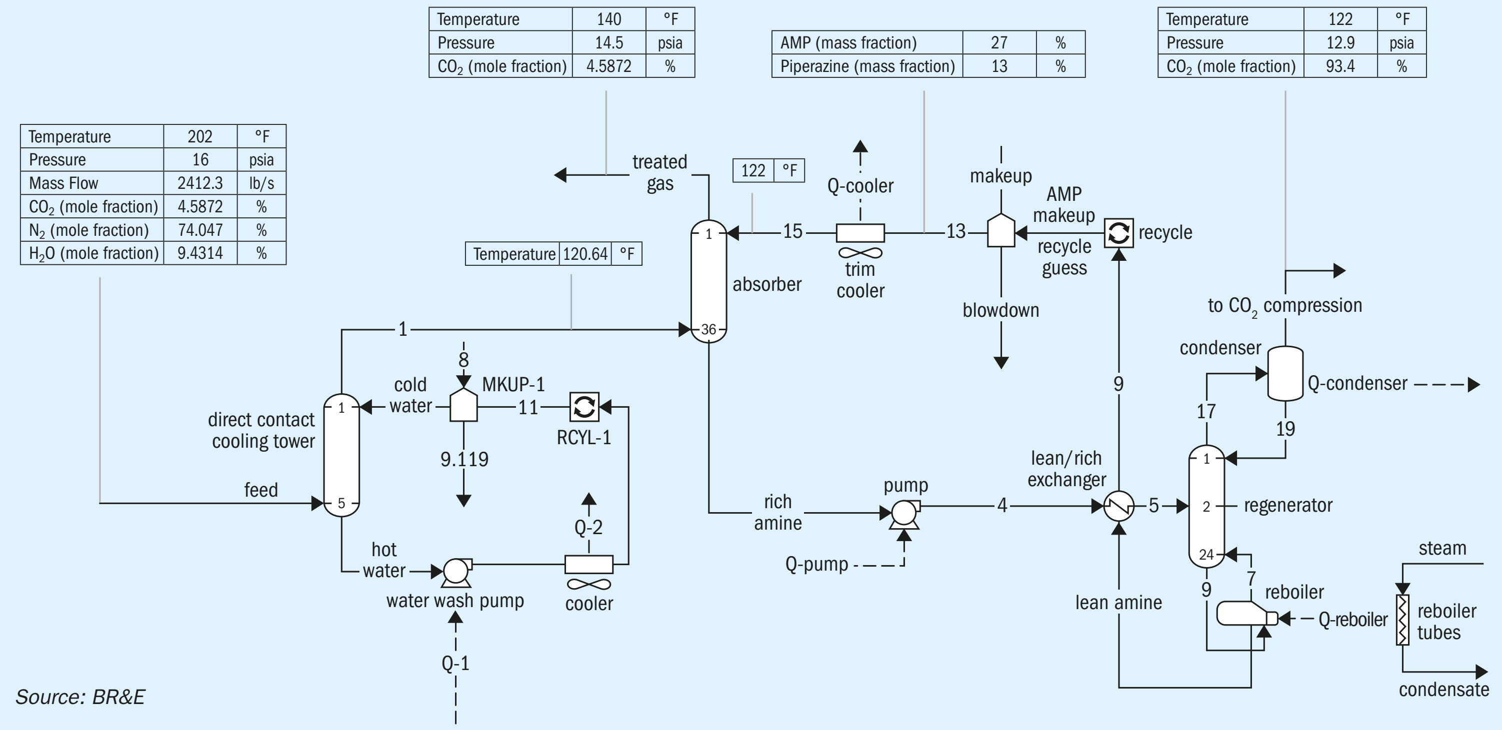
A conventional sour gas facility is an energy intensive process. In the push for decarbonising this value chain, three exit points were identified as opportunities to capture CO_2 from. However, just like other units of a gas plant (e.g. AGRU, GDU, AGE, SRU), a carbon capture unit also requires energy to operate and therefore has its own "footprint". It almost seems counter-intuitive to even propose such a unit. However, it's the volume balancing and net zero game that need to be focused on. By utilising the right technologies and modifications this can be achieved in a cost-effective manner. Some suggestions discussed in this article are:

- COPE or oxygen-enhanced SRUs;
- using AMP/PZ and variants over MEA at low pressures to save on solvent regeneration costs;
- using packed towers (to provide better CO_2 mass transfer at LP) instead of trays;
- SOx pretreatment (to prevent amine degradation/HSS).

References

1. ProMax 6.0, Bryan Research and Engineering, LLC, Bryan, Texas, 2024.
2. BRE231 Amine Sweetening Training Manual, Bryan Research and Engineering, LLC, Bryan, Texas, 2024.

Fig 8: **Proposal CO_2 capture plant (ProMax process model)**



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