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Number 415

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SULPHUR

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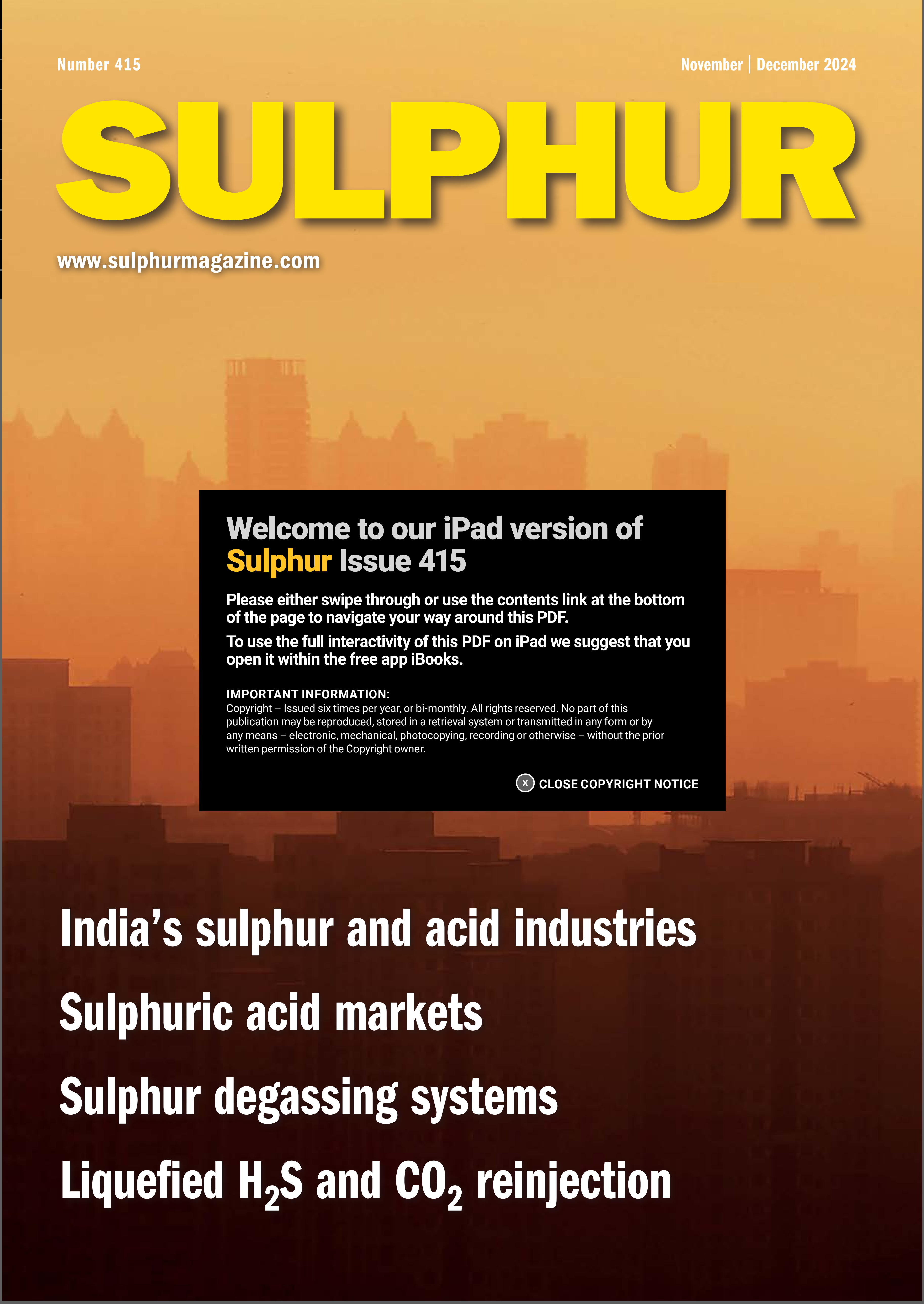

India's sulphur and acid industries

Sulphuric acid markets

Sulphur degassing systems

Liquefied H_2S and CO_2 reinjection

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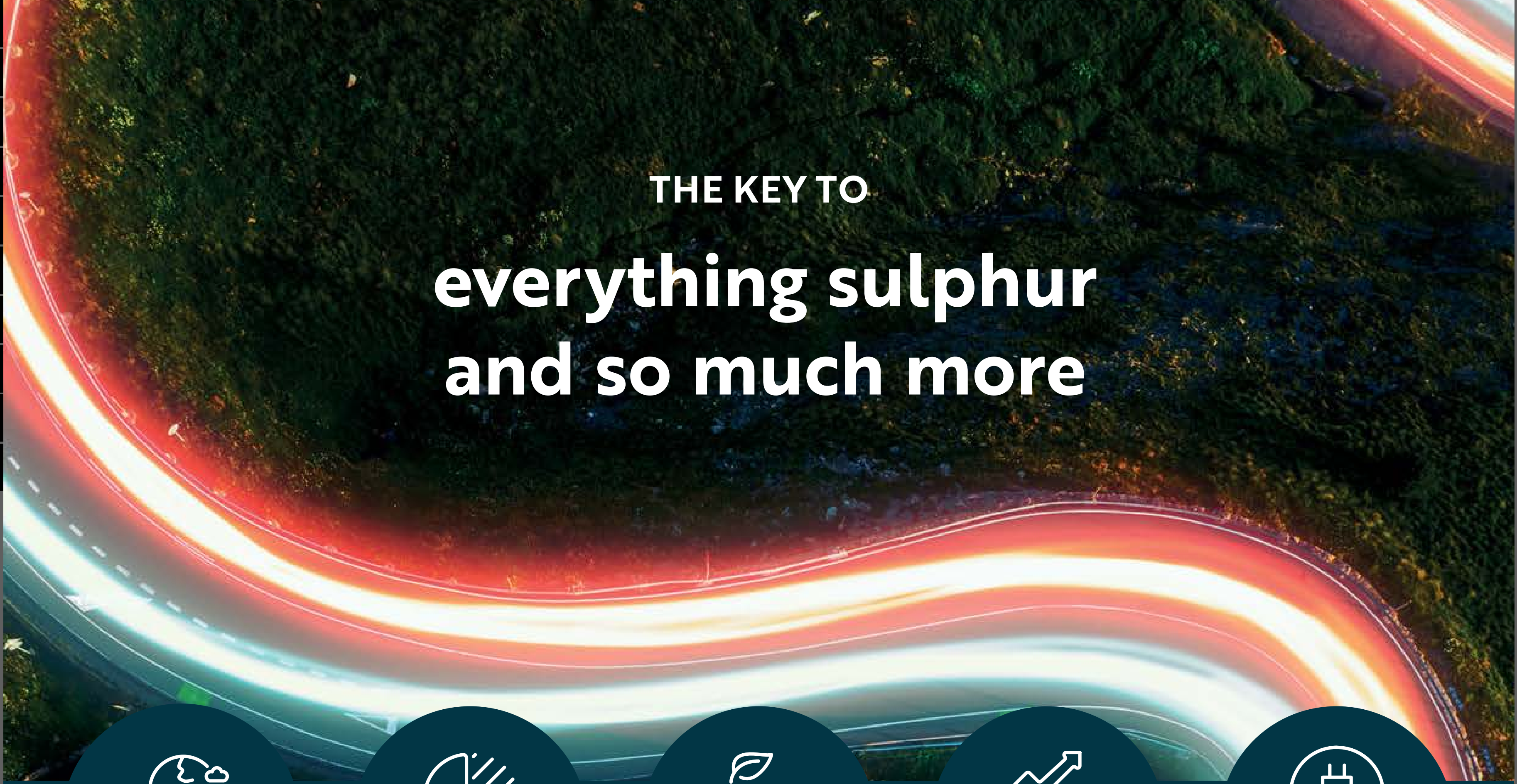

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SULPHUR

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NUMBER 415 NOVEMBER | DECEMBER 2024

Cover: *Golden layers of sunset in city of Mumbai. Photo: Jeet khagram/ Shutterstock.com*

Acid markets

How long will market tightness last?

Sulphuric acid equipment

Chemetics' key innovations over six decades

Read this issue online at: www.sulphurmagazine.com

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CRU

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REGULARS

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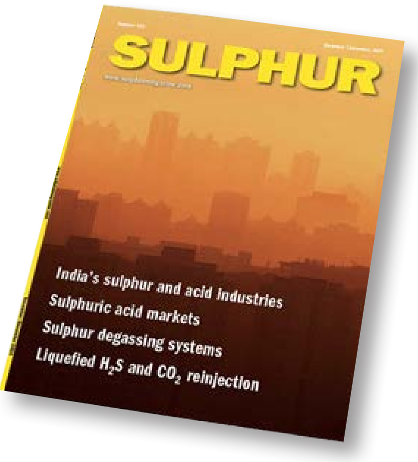
Morocco's phosphate drive



OCP's recent award of a contract to Worley Chemetics for three new greenfield sulphuric acid plants has confirmed the phosphate giant's plans for its new Mzinda Phosphate Hub in Morocco, one of the largest investments in new phosphate capacity anywhere in the world over the next few years. It is part of a number of new investments under way in Morocco as OCP continues to expand its already considerable phosphate facilities. Three new fertilizer lines came onstream at Jorf Lasfar in 2023 and 2024, each with a capacity of 1 million t/a of diammonium phosphate (DAP). The Mzinda mega-project will add another 4 million t/a of triple superphosphate (TSP) capacity by around 2028-29, and will relieve some of the issues that OCP has in importing ammonia for DAP production, as TSP only requires phosphate rock and phosphoric acid. There is also an additional 1 million t/a of TSP capacity under construction at Jorf Lasfar, which is expected to be completed next year, and OCP also announced last year that it would build an integrated purified phosphoric acid (PPA) plant at Jorf Lasfar. The first phase of the project consists of 200,000 t/a of P_2O_5 pretreated phosphoric acid capacity, 100,000 t/a (P_2O_5) of PPA capacity, and 100,000 t/a of technical MAP (tMAP) capacity. The site will also be home to downstream production of phosphate salts and lithium iron phosphate (LFP) capacities. The initial plants will be delivered starting in mid-2026, carrying through into 2029, constructed in conjunction with JESA, a joint venture between OCP and Worley.

> **"All of this additional processed phosphate capacity will of course necessitate importing large amounts of sulphur..."**

These announcements build on already aggressive expansions in downstream phosphate capacity that OCP has been building over the past two decades, and which have seen OCP's share of the world finished phosphate market grow to reach 28% in 2023, overtaking China to become the world's largest exporter in 2020. Aside from Saudi Arabia's Ma'aden III Phosphate project, almost all of the incremental supply in the phosphate market in the medium term will come from Morocco. In order to meet these new commitments, OCP intends to dramatically increase its rock production capacity to 70 million t/a by 2028, up from 47.5 million t/a in 2023. While this figure may be too ambitious even for OCP, the company remains possessed of 75% of the world's estimated phosphate reserves, and has the lowest cost production capacity. Consequently, OCP seems set to continue to exert its dominance over the global phosphate market.

As Morocco has very little domestic sulphur production or metal smelting capacity, all of this additional processed phosphate capacity will of course necessitate importing large amounts of sulphur and sulphuric acid and the construction of new sulphur burning sulphuric acid plants in Morocco, such as the Chemetics ones slated for Mzinda. Morocco is expected to use 7.4 million t/a of sulphur in 2024, and this could rise to 9.3 million t/a by 2029, possibly even leading to Morocco overtaking the USA as a consumer of sulphur, and putting it second only to China. Most of this sulphur is likely to be sourced from the Middle East, particularly the large new refinery and sour gas projects coming on stream over the next few years, and Morocco may be a key factor in balancing potential market oversupply over that period.

Richard Hands, Editor

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Price Trends

SULPHUR

Global sulphur prices underwent increases in some key benchmark markets during October, but spot activity nevertheless remained muted, with demand subdued and availability tight. Market participants continue to closely track geopolitical developments.

The Qatar sulphur price (QSP) for November was posted at $136/t f.o.b., up $12/t from the October level. This represents the highest QSP since January 2023's at $155/t f.o.b., and reflects delivered levels to China in the high $150s/t c.fr at current freight rates. Prices in the Middle East have been on the rise recently, with the spot price assessed at a range of $139-141/t f.o.b., and a Muntajat tender of 35,000 tonnes was believed to have been awarded at around $140/t f.o.b., according to market sources. The ADNOC monthly contract for Q4 was finally confirmed settled at $122/t f.o.b., and ADNOC's monthly contract price for November was settled at $135 /t f.o.b. Prices at these level narrows the spread to benchmark prices in China and Indonesia, making those trade less viable.

Prices in China have also increased for both delivered and port prices, with import prices now assessed at $152-157/t c.fr following reports of transactions occurring across the price range. A major phosphate producer in Hubei province purchased 20,000 tonnes of Canadian sulphur at $157/t c.fr at the end of October. This follows a trade the previous week involving Canadian sulphur to the Yangtze River at $154/t c.fr. According to market sources, other transactions were concluded around the same range. A trader sold a cargo to another trader at around $154-156/t c.fr and a southwest Chinese phosphate producer bought a cargo at $152/t c.fr. The high-end for port transactions reached RMB1,300/t FCA ($183/t), the highest level since March 2023, indicating a netback range at around $154/t c.fr. Following the increase, downstream consumers stepped back from buying, which led to port prices declining slightly. Market sentiment is positive due to the affordable prices and high phosphate operating rate. The countrywide MAP production operating rates increased by 2% to about 57%, according to local sources. The operating of DAP is reported at 57%, down 2%, across the whole country.

Total sulphur port inventories in China declined by 78,000 tonnes to 2.31 million tonnes by 30 October. The volume at Yangtze River ports increased 22,000 tonnes to 844,000 tonnes, whereas the Dafeng port inventory decreased 51,000 tonnes to 499,000 tonnes. Sinopec's Puguang, the largest sulphur producer in China, kept its sulphur prices at port and Dazhou factory prices unchanged. Daily production is around 4,300 t/d in Wanzhou and 930 t/d in Dazhou. Factory prices at Dazhou were unchanged at RMB1,180/t EXW ($166/t) for both truck and rail volumes.

The spot price assessment for sulphur cargoes to Indonesia was up to $150-155/t c.fr after five consecutive weeks at its previous price level of $145-147/t c.fr. The latest transactions have concluded towards the middle point of the newly published range, according to market sources. Additionally, PT Lygend awarded a tender early last week at a price around $152/t c.fr. In spite of concerns that higher sulphur prices from the Middle East have made trade less viable for both China and Indonesia, it is believed that sulphur consumption in Indonesia will still increase further this year, though demand may be partly offset by increased domestic smelter acid production.

European sulphur contracts for the fourth quarter have settled at an increase of $30/t from Q3. The published ranges are $154-184/t c.fr Benelux for barge/railcar and $173-213/t CPT NW Europe truckload. A rise in settlement prices was widely expected due to global price increases in Q3 and the tight availability in the region. The Baltic spot price was assessed up to $100-110/t f.o.b. from $85-90/t f.o.b. based on delivered prices to Brazil at $140-150/t c.fr.

A recent CMOC tender awarded at $145/t c.fr which is understood to be of Kazakhstan origin would signal an FOB price at this range with current freight rates around $22-25/t. Kazakhstan cargoes are predominantly transported via rail to the port of Ust-Luga and into the Baltic Sea. For Q1-Q3 2024, Kazakhstan exported 3.63 million tonnes of sulphur. This represents a year-on-year increase of 30%. Its main export partners during this period have been Morocco with 2.62 million tonnes, Israel with 326,000 tonnes, and Senegal with 227,000 tonnes. Cargoes to Brazil were 49,000 tonnes and Argentina 21,000 tonnes. Spot prices for sulphur cargoes to Brazil were assessed flat at $140-150/t c.fr for the second consecutive week.

In North America, spot prices for seaborne sulphur exports from Canada rose slightly to $110-118/t f.o.b., up from previous assessments of $108-115/t f.o.b., amid low spot trading activity. Recent transactions into China, involving Canadian sulphur cargoes sold at $154-157/t c.fr, would place the netback in this current assessed FOB range, and global price climbs suggest that prices in China are likely to increase further, but activity in Canada remained lacklustre.

India's sulphur prices held unchanged at $140-145/t c.fr as steady contract shipments continued to meet demand, offsetting tight supply. Iffco's recent procurement of spot cargoes from its regular Middle Eastern suppliers had minimal impact on overall price and demand. Iffco secured approximately 80,000-90,000 tonnes of sulphur at mid-$140s/t c.fr India in a deal that was finalised in mid-October. The company is understood to renew its purchasing of sulphur around the end of November. Indian sulphur imports surged in October to 172,000 tonnes, which is a 35% year-on-year increase.

SULPHURIC ACID

Sulphuric acid benchmarks were largely unchanged at the end of October. In Asia, China's export price was assessed at $50-55/t f.o.b., for the second consecutive week with availability for the spot market expected until November as tight spot availability offset a lack of demand. The higher end of the range could be edging higher towards $60/t f.o.b., according to market participants, but no deals were reported concluded at this level at the time of writing. The Daye smelter incident on 14 September brought a minor rebalancing in the Chinese market with other producers adjusting but prices are reflecting the reduced availability. The Daye smelter in Hubei province was forced to shutdown its main operations after a fire, with the ensuing shutdown expected to last for three months. In spite of the removal of 1 million t/a of acid capacity from the market, it is not expected to impact the market significantly, as it may actually boost supply at other smelters - because raw material availability is tight, there are plenty of buyers for what Daye is

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unable to produce. It may also boost sulphur demand in the short term to plug the domestic gap. Supply is very tight and no spot availability is expected until the end of November or early December, according to market sources.

The spot market for Japan and South Korea has been pegged up to $45-50/t f.o.b. Although transactions have been limited due to tight availability, at least one cargo has been offered within the newly published range. The published index is assessed up at $-5-50/t f.o.b., with the lower end representing contracts. Q4 contract prices for supply to China were indicated as settled at around the high $20s/t c.fr. Based on current freight rates, the $-5/t at the lower end of the range, therefore, remains possible.

Prices for sulphuric acid to Turkey were assessed up at $140-150/t c.fr for spot and contract sales. This would represent a $25/t increase to the range, which previously stood at $115-125/t c.fr. Turkish imports for January-August 2024 were up 63% year on year at 525,000 tonnes, with 97% of this from Bulgaria, according to data via Global Trade Tracker (GTT). Turkey's exports of sulphuric acid, from January-August 2024, reached 120,000 tonnes, a year-on-year increase of 600%. The main export partner for this period was Morocco, which received around 97,000 tonnes.

The North African spot price range for sulphuric acid narrowed to $140-160/t, rising on the lower end of the range from previous assessments of $110-160/t c.fr. Tight availability, high European prices and current freight rates have edged prices higher. From January-August 2024, Morocco imported sulphuric acid primarily from China, with volumes reaching 304,000 tonnes, followed by Bulgaria with 189,000 tonnes and Spain with 156,000 tonnes, according to Global Trade Tracker data.

India's sulphuric acid market remained stable, with prices flat at $102-110/t c.fr, on weak spot demand. No spot deals were reported in the market in late October as several regular importers held off on new purchases. Offer prices are currently in the $105-110/t c.fr India range amid tight supply, but saw no buyers stepped in at these levels. Chinese offers are still around $55-60/t f.o.b., which would suggest a higher delivered price at $110-115/t c.fr India. However, other f.o.b. offers were heard in the mid-$40s/t range, bringing c.fr India to approximately $100/t. The market remains cautious over reduced import demand amid increased domestic production. Growing output from Indian smelter plants has tempered the need for imports, adding to price stability. Additional shifts in market supply are anticipated with PPL's upcoming sulphuric acid facility expected to launch next year and potential capacity developments at Greenstar, which could further reduce import volumes. India's October sulphuric acid imports reached approximately 142,000 tonnes, reflecting a slight 5% year-on-year decline.

Sulphuric acid prices for sales into Brazil were unchanged at $160-170/t c.fr for the fourth consecutive week on limited demand. Current European f.o.b. prices in the $100-110/t range and NW Europe-Brazil freight rates around the $50s/t, make delivered prices in the $160s/t c.fr in theory possible. The higher end of the range could be edging to the mid-$170s/t, according to some market participants. Last month, Brazil's imports of sulphuric acid fell by 18% to 49,850 tonnes, down from September 2023 at 60,854 tonnes. Brazil's annual record remains 2022 when imports of acid totalled 845,000 tonnes.

Spot prices for sulphuric acid sales into Chile were assessed unchanged at $170-175/t c.fr for the fourth consecutive week. However, no fresh spot sales or enquiries were reported. Chile will be celebrating two national holidays on the 31 October and 1 November so limited remained activity in the markets. From January to August 2024, Chile has imported 2.19 million tonnes of acid, which is a decrease of 18% compared to volumes in the same period in 2023. In the month of August 2024, Chile imported 226,000 tonnes of sulphuric acid which represents a 35% increase compared to August 2023. The biggest imported volume came from Peru with 90,484 tonnes, followed by Japan with 35,932 tonnes and China with 31,938 tonnes. ■

Price Indications

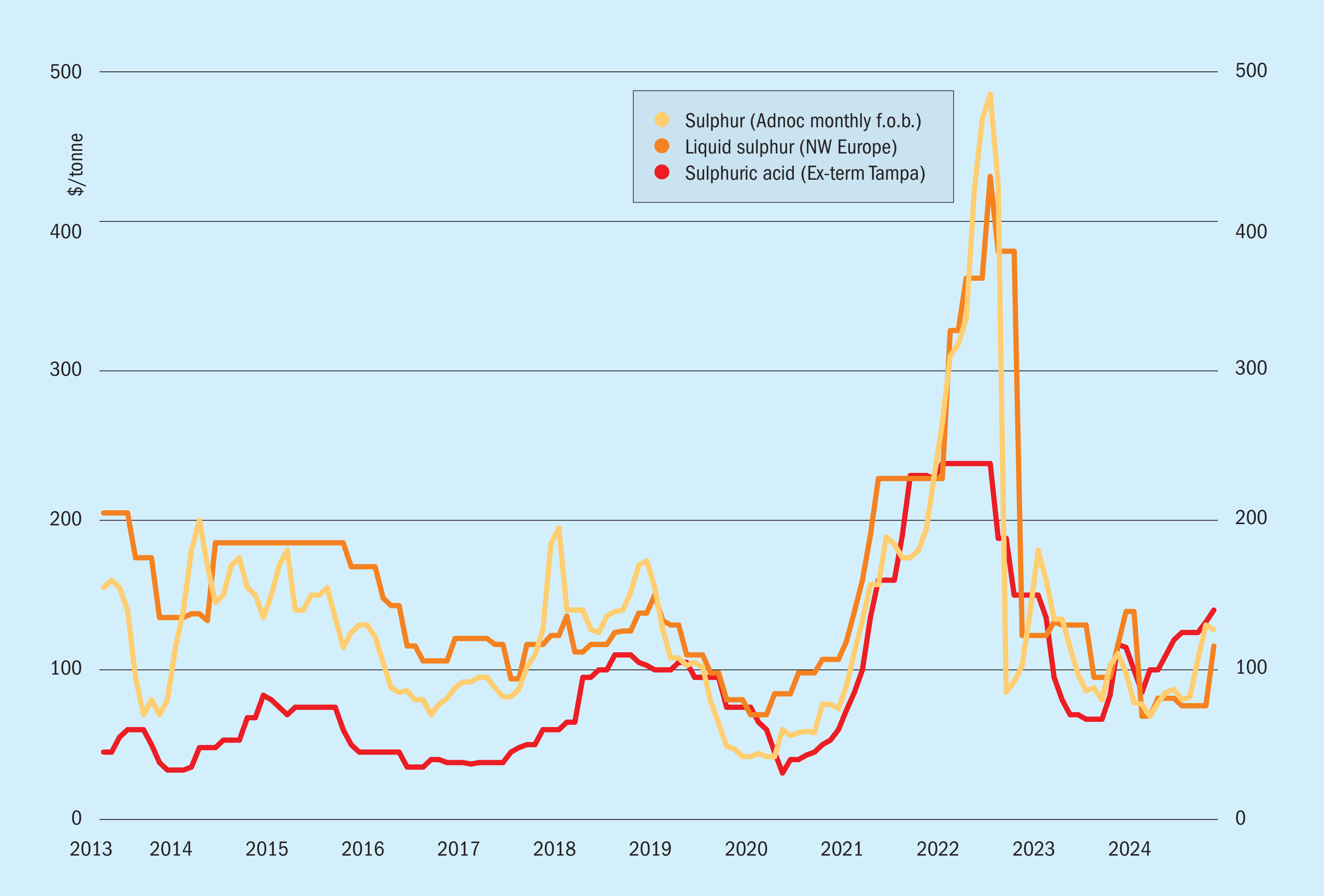
Table 1: **Recent sulphur prices, major markets**

Cash equivalent	June	July	August	September	October
Sulphur, bulk ($/t)					
Adnoc monthly contract	80	82	107	130	127
China c.fr spot	103	125	143	145	154
Liquid sulphur ($/t)					
Tampa f.o.b. contract	76	76	76	76	116
NW Europe c.fr	158	163	163	163	193
Sulphuric acid ($/t)					
US Gulf spot	125	125	125	132	140

Source: CRU

Market Outlook

Historical price trends $/tonne



Source: CRU

SULPHUR

- Global sulphur prices are expected to continue rising in certain regions but at a reduced rate of increase. Recent higher spot prices in the Middle East are likely to carry over to other markets. Sulphur affordability in key markets such as China remains good, reinforced by recent increases in phosphate prices.
- This was visible at the start of November as CIL in Indian was understood to have secured a cargo in the mid-$150s/t c.fr via a trader, with tonnes from ADNOC, although Indonesian prices were not seen to have risen as yet.
- In spite of concerns that higher sulphur prices from the Middle East have made trade less viable for both China and Indonesia, it is believed that sulphur consumption in Indonesia will still increase further this year, though demand may be partly offset by increased domestic smelter acid production.
- Major stock drawdowns this year, particularly from Kazakhstan, appear to have masked underlying tightness in the market, and as Kazakh stockpiles become exhausted next year, longer term prices are likely to rise, with markets tight until the start up of major Middle Eastern new sulphur capacity in a couple of years time. China has been building inventory at ports this year, with stocks up to 2.5 million tonnes, giving buyers some flexibility in negotiating contracts going forward.

SULPHURIC ACID

- Global sulphuric acid spot prices are likely to remain steady in the coming weeks as supply is tight globally. A gradual decline is expected towards the end of the year. Shifts in supply/demand dynamics will determine the pace and rate of this decrease.
- Lack of availability of copper concentrate continues to constrain Chinese smelter acid production, but this also means that outages such as at Daye will be offset by higher production from other smelters, keeping output relatively constant.
- Growing output from Indian smelter plants has tempered the need for imports, adding to price stability. Additional shifts in market supply are anticipated with PPL's upcoming sulphuric acid facility expected to launch next year and potential capacity developments at Greenstar, which could further reduce import volumes.
- Key import markets such as Morocco, Indonesia and India are likely to reduce acid imports in 2024 H2 in favour of burning sulphur. Morocco is expected to commission two new sulphur-burners, which should lead to a reduction in imports by Q4 2024. In Indonesia, despite the recent fire at PT Freeport's newly inaugurated Gresik smelter, other projects are scheduled to come online, adding volume in 2025. ■

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Sulphur Industry News

AZERBAIJAN

Contracts awarded for SRU upgrade


PHOTO: SOCAR

The Heydar Aliyev refinery, Baku

NextChem has been awarded two contracts to upgrade and expand the capacity of the Heydar Aliyev Oil Refinery (HAOR) industrial complex in Baku by state oil company SOCAR. As part of the contract, NextChem will conduct a technological assessment and deliver a process design package to upgrade the existing sulphur recovery unit (SRU) with oxygen enriched air, a cost-effective and flexible solution for expanding its current sulphur production capacity. Additionally, NextChem will provide the licensing and the process design package based on its proprietary NX SulphuRec™ technology for a new SRU. NX SulphuRec™ is a portfolio of proprietary sulphur recovery technologies, based on the integration of modified Claus and tail gas treatment processes, aimed at reducing the environmental impact of acid and sour gases produced during the refining process.

Alessandro Bernini, CEO of NextChem's owning group Maire, commented: "These awards confirm the mutually beneficial relationship with SOCAR to develop Azerbaijan's natural resources transformation activities. We are eager to further support the upgrade of the Baku HAOR complex with our technologies that ensure the highest environmental standards." ■

KAZAKHSTAN

KPO completes gas reinjection project

Karachaganak Petroleum Operating BV (KPO) says that its KEP-1A project has safely achieved first gas reinjection. The project milestone was reached with the successful operation of the fifth compressor at full discharge pressure, enabling gas from the Karachaganak Processing Complex (KPC) to be reinjected into the reservoir through the new gas reinjection system for the first time. The company says that this demonstrates KPO's ongoing commitment to safe, responsible and efficient operation of the giant Karachaganak field. The compressor is set to significantly boost gas re-injection volumes, maintaining reservoir pressure and extending the field's liquid production plateau. The project has progressed successfully despite external challenges such as geopolitical tensions, logistical restrictions, and a "supply chain crisis". KPO is a joint venture between Eni, Shell, Chevron, Lukoil and state-owned KazMunaiGaz.

The parallel $730 million KEP-1B project is also under construction, including a sixth injection compression facility, gas dehydration unit, expansion of the gas gathering network and other associated facilities. Like KEP-1A, the EPC contractor is Italy's Sicim. Completion is expected in 2026. However, while much of the associated sour gas is reinjected, the Kazakh government has also been pressing the project partners to move forward with a long-standing plan to build a dedicated 3.6 bcm/year gas processing plant to increase supplies of network gas to consumers in the country, which would boost sulphur recovery from the project.

Kashagan partners in talks on sulphur fine

Partners in the huge Kashagan project have reportedly restarted talks with the government of Kazakhstan over a prospective $5 billion lawsuit for alleged breaches of sulphur storage regulations. The Kashagan oil field is operated by the North Caspian Operating Consortium (NCOC), which includes Eni, Shell, ExxonMobil and TotalEnergies. The Kazakh government claims that NCOC breached its permitted sulphur stockpile of 700,000 tonnes by an additional 1 million tonnes, as well as alleged releases of sulphur dioxide and untreated waste water. The operating companies have not commented on the matter, but there is a widespread belief in the industry that the government is attempting to use the fine as leverage for financial advantage, as they did in a similar situation with KPO a decade ago. Bloomberg reports that there is an no fault offer on the table of $110 million of investment in social projects recoverable from the production sharing contract, and a social development fund, as well as an agreement over LPG pricing in exchange for the removal of the fines. NCOC won a court challenge to the environmental rulings, but this was overturned by an appellate court decision, and the case has moved to the country's Supreme Court.

NextChem to collaborate on SAF

During the Kazakhstan-Italy Forum held in Milan in early October, NextChem and state gas company KazMunaiGas (KMG) signed an agreement to collaborate on advancing energy transition initiatives, using NextChem's proprietary technology portfolio and process engineering capabilities. These initiatives aim at contributing to the decarbonisation and upgrade of Kazakhstan's industry, in particular for the production of sustainable aviation fuel and low-carbon hydrogen through CO_2 capture, as well as for the implementation of circular solutions. NextChem and KMG will evaluate the feasibility of development initiatives in the country, involving NextChem sister company Tecnimont for the assessment of engineering, procurement, and construction activities when projects advance to the execution phase.

Alessandro Bernini, CEO of Maire, commented: "As one of the world's leaders in the energy space, Kazakhstan is a strategic and valuable partner for us.

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In fact, the combination of the Country's resources with our Group's technologies and engineering know-how represents a unique opportunity to drive the global shift towards a sustainable and low-carbon economy. We are eager to make this journey together".

UNITED STATES

New lithium sulphur battery 'gigafactory' announced

Lithium sulphur batter manufacturer Lyten has announced plans to invest more than $1 billion to build the world's first lithium-sulphur battery "gigafactory" near Reno, Nevada. It will have the capacity to produce up to 10 GWh of batteries annually at full scale. Phase 1 of the facility is scheduled to come online in 2027. Lyten's factory will manufacture cathode active materials (CAM) and lithium metal anodes and complete assembly of lithium-sulphur battery cells. Lyten says that its lithium-sulphur cells have a high energy density, enable up to 40% weight savings compared to lithium-ion cells and 60% less than lithium iron phosphate (LFP) batteries.

A 3D rendering of the planned Lyten facility near Reno.

CSB launches investigation into H_2S leak

The US Chemical Safety and Hazard Investigation Board (CSB) says that it is launching an investigation into a fatal release of hydrogen sulphide at the Pemex petroleum refinery in Deer Park, Texas, on October 10th. Two contract workers died as a result of the release, and an additional 13 workers reportedly were transported to local medical facilities.

CSB Chairperson Steve Owens said, "This is a very serious incident that caused multiple fatalities and injuries and potentially put the surrounding community at risk."

The release at the Pemex refinery, which is located about 18 miles east of Houston, also prompted a shelter-in-place order for two neighbouring cities, and a portion of Texas State Highway 225 was closed temporarily.

UNITED ARAB EMIRATES

Linde to supply CCS for Hail/Ghasha

Linde Engineering has won the contract to provide carbon capture technology for ADNOC's $17bn Hail and Ghasha sour gas field development project. The deal has been awarded to Linde as a subcontract by NextChem, a subsidiary of Italy-based Maire, the main EPC contractor for the onshore package of the Hail and Ghasha project. As part of its contract, Linde will provide its adsorption-based carbon capture technology Hisorp CC, plus the core units, to capture and purify CO_2 for carbon capture and storage (CCS). The CO_2 recovery facility will have a total capacity to capture and store 1.5 million t/a of CO_2 emissions from the Hail and Ghasha scheme.

Hisorp CC is an electrically-driven technology that combines pressure swing adsorption with cryogenic separation and compression to achieve CO_2 capture rates of over 99%. The process does not require steam for regeneration, so it does not increase the carbon footprint, Linde says.

INDIA

Siwertell commissions sulphur unloader for Paradeep Phosphates

Bruks Siwertell says that it has commissioned a second Siwertell ship unloader for Paradeep Phosphates Ltd (PPL) in India. The new ST 640 D-type ship unloader joins a similar Siwertell unit at the port of Paradeep, in Odisha province. PPL's first unloader was delivered in 2006 and was part of the port's environmental transformation. PPL, part of the KK Birla Group and the OCP Group of Morocco, is a major manufacturer of phosphate fertilizers and is Asia's second largest producer of diammonium phosphate (DAP), sourced from its plant close to the port.

"PPL has very high expectations of Siwertell technology," said Bengt Svensson, Senior Contract Manager, Bruks Siwertell. "The delivery of our original Siwertell ship unloader, almost two decades ago, saw PPL switch from open-air sulphur handling with grab cranes, to safe, fully enclosed, dust-free operations. It literally transformed the port environmentally and was a significant step-up in efficiency. To keep up with demand, PPL needed to increase capacity, but wanted to do this in the most sustainable and environment-friendly way possible, leading to the second order," he added.

The new rail-mounted ship unloader operates on the same jetty as Bruks Siwertell's previous delivery for PPL, and similar to the first unit, has the capacity to discharge sulphur from vessels up to 60,000 dwt in size, at a rated capacity of 1,500 t/h. It alternates handling this cargo with rock phosphate at a rate of 1,200 t/h and muriate of potash (MoP) at 1,050 t/h. Both units are fitted with the Siwertell Sulphur Safety System (4S), which was first developed over 30 years ago to minimise the risk of explosions when handling this volatile and corrosive material. In open-air handling systems, such as grab cranes, the flammable and explosive nature of s ulphur is not so much of a problem, but becomes an issue for enclosed systems. However, sulphur should be contained, and its dust minimised, as it is damaging to the environment. ■

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Sulphuric Acid News

MOROCCO

OCP Group to boost fertilizer production

OCP Group has launched what it calls the Mzinda-Meskala Strategic Programme, aimed at significantly expanding fertilizer production in the country. Initially announced in December 2022, the program is set to enhance production capacity in two key regions: the Mzinda-Safi Corridor and the Meskala-Essaouira Corridor. This initiative is part of OCP's broader strategy to meet growing global demand for fertilizers while committing to long-term sustainability goals, including achieving carbon neutrality by 2040.

The programme has two primary objectives: boosting fertilizer production to strengthen OCP's global supply capacity and adhering to its environmental goals. It aims to develop a new mine in Meskala and construct a state-of-the-art chemical and mining complex in Mzinda, both of which will process phosphate rock from key deposits in Ben Guerir, Youssoufia, and Meskala. By 2028, OCP plans to reach an annual production capacity of 12 million t/a of rock, 3 million t/a of phosphoric acid, and 8.4 million t of fertilizers within the Mzinda-Safi Corridor. Simultaneously, the Meskala-Essaouira Corridor is projected to produce 20 million t/a of phosphate rock, 1 million t/a of phosphoric acid, and 2 million t/a of fertilizers.

A central aspect of the programme is a focus on cost control and optimising the value chain. The expansion is designed to ensure that OCP can continue to meet rising demand in key global markets, including Europe, Africa, and India. By increasing production capacity while maintaining a strong focus on efficiency, the group aims to remain competitive in a highly dynamic global fertilizer market. ■

AUSTRALIA

IncitecPicot considering closure of Phosphate Hill

IncitecPivot is conducting a strategic review of its operations over the next 6-12 months, and “considering all options” according to CEO and managing director Mauro Neves, speaking to an investor meeting. CFO Paul Victor added that the company is assuming that its Phosphate Hill operations will be closed in the near future, but the company is still evaluating whether this will be an outright closure, a move to ‘care and maintenance’, or whether it was still possible to “utilise other parts of the asset in still a very productive manner”. The company is also working with the Queensland Government to determine the possible costs to remediate the site. Phosphate Hill has faced issues with flooding, rail line and gas supply disruptions and uneconomic production costs for its diammonium phosphate output in recent years and last year cut production rates.

In the meantime, Neves said that IncitecPivot continues to look for a buyer for the company. “We truly believe that under different ownership IPF should benefit from greater synergies and operational efficiencies,” he said. “This includes a full sale of the business or the selling of the business in its parts.” Prior talks on a sale with PT Pupuk Kalimantan Timur broke down in July 2024.

PHOTO: INCITEC PIVOT

Incitec's Phosphate Hill site

UNITED STATES

OCP says phosphate tariffs may be withdrawn

OCP Group says that it understands that Mosaic has withdrawn its request to the US Department of Commerce (DoC) for a third annual administrative review of the countervailing duties imposed on Moroccan imports of phosphate fertilizers to the US. OCP said it expects the DoC to rescind the duties in the coming weeks. These tariffs were initially set at 19.95%, but have been provisionally reduced to 7.42%. OCP said that it hopes “this development will prove to be a first step toward ending these tariffs that are preventing US farmers from having reliable access to a high-quality supply of an essential input for growing abundant and healthy crops to feed their fellow citizens and compete in global markets.” It also said that it would continue to pursue appeals against these tariffs in the Court of International Trade.

Hurricanes affect phosphate production

Florida has seen extensive damage from hurricane Helene, which made landfall on September 26th, and hurricane Milton, which arrived on October 10th. Tampa received around 18 inches of rainfall from the extreme weather event in October, which left three million Florida homes and business without power in the immediate aftermath.

Mosaic said on October 21st that recovery efforts post hurricanes “have progressed well with all Florida production facilities having returned to normal operations except Riverview which has resumed production and is expected to return to normal rates by the end of the week.” The company also confirmed that Mosaic's mining sites were starting to resume operations. South Fort Meade was expected to return to normal within days, while Four Corners was expected to revert to normal working toward the end of October.

Florida accounts for around 85% of Mosaic's finished fertilizer production, and US DAP/MAP supply has been very tight for months. Nutrien's White Springs production plant, around 180 miles north of Tampa, received some damage from hurricane Helene and was still out of action, as of 11th October, while Nutrien assessed the damage and repairs required.

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SENEGAL

Coromandel increases stake in BMCC

Coromandel International says that it intends to invest $3.84 million in Senegalese phosphate rock mining company Baobab Mining and Chemicals Corporation (BMCC), as well as loaning BMCC a further $6.5 million to fund expansion projects and meet working capital requirements. The acquisition will take Coromandel's overall shareholding in BMCC to 53.8%. BMCC, incorporated in 2011, has a renewable exploitation permit for processing phosphate ore. Coromandel acquired a 45% stake in the company in September 2022. The company has since stabilised mining operations and is currently commissioning a fixed processing plant to optimise rock production. The increased output will support securing phosphate rock for the upcoming phosphoric acid plant development at the Coromandel's Kakinada unit in India.

Commenting on the investment, Coromandel International managing director and CEO S. Sankarasubramanian said: "with India importing the majority of its rock requirement, investment in rock phosphate mines will be critical for attaining long-term supply security for its phosphate fertiliser production. The additional stake in BMCC is strategically important for capturing value chain and building self-sufficiency in our operations," Sankarasubramanian noted.

INDIA

Metso delivers scrubbers for SO_2 emissions reduction

Metso will deliver four Peracidox™ scrubbers to Hindustan Zinc to minimize sulphur dioxide emissions at their plants. The scrubbers will be installed at the sulphuric acid plants at the company's zinc smelters in Chanderiya and Debari in India. The scrubbers have been customised for the Indian market to comply with the local environmental regulations and to meet the needs of the Indian customers, according to Hannes Storch, vice president, Metals and Chemical Processing at Metso.

The Peracidox™ scrubbers reduce the residual SO_2 of tail gases, minimising emissions. The solution, an oxidative removal process, features high removal efficiency and ease of control with minimised mechanical equipment.

ANGOLA

Loan finalised for phosphate project

Minbos says that the Fundo Soberano de Angola (FSDEA), the Angolan sovereign wealth fund, has approved a $10 million strategic investment in Minbos, to support the construction of the Cabinda Phosphate Fertilizer Project. Formalities to finalise the strategic investment will commence immediately and are subject to all the normal regulatory and other approvals. FSDEA completed its due diligence in co-operation with the Industrial Development Corporation (IDC) of South Africa, and understands its investment will enable the Company to meet IDC's condition precedent of raising $11 million for equity funding to support the development of the CPFP. Minbos expects to finalise the balance of IDC's conditions precedent for the $14 million construction funding provided by the IDC in the coming weeks.

The Cabinda phosphate project is an open-pit mining and fertiliser production project in the enclave of Cabinda, north of Angola. It is being developed by a joint venture between Minbos Resources (85%) and local partners (15%). At peak it will mine 1.2 million t/a of phosphate-bearing rock at 30.1% P_2O_5 grade, with an ore processing plant capable of generating 187,000 t/a.

ZAMBIA

Contract for copper project

Barrick Gold Corporation has awarded Metso a contract for the supply of copper concentrator plant equipment to their Lumwana expansion project in North-Western Province in Zambia. Metso's scope of delivery includes key equipment for grinding, flotation, thickening, feeding and filtration. The value of the order is approximately euro 70 million.

Lumwana is a significant contributor in Barrick's copper portfolio, catering to the rapidly increasing demand for copper required for the energy transition. Barrick says that the project is also elemental in reviving Zambia's copper industry and contributing to the local economy, and will turn Lumwana into one of the world's major copper mines, with projected annual production of 240,000 t/a of copper.

"We are honoured to have been selected by Barrick as the strategic partner for this project. The copper concentrate production process in Lumwana has been designed with sustainability and production efficiency in mind, with most of the equipment selected from our Planet Positive offering," said Markku Teräsvasara, president of the Minerals business area and deputy CEO of Metso.

SWEDEN

Iron ore miner LKAB outlines phosphate market re-entry

CRU has visited Swedish iron ore producer LKAB's vast Kiruna underground mine to see the company's early-stage plans for valorising its phosphate-bearing (apatite) tailings. LKAB ultimately intends to produce both a rare earth element (REE) concentrate and ammoniated phosphates at a planned facility in Luleå as part of a wider company strategy to decarbonise its iron production and extract "critical" minerals from its waste streams.

The "ReeMAP" project will potentially generate merchant-grade phosphoric acid (MGA) for export. Despite the large scale of its iron ore output – 26.2 million t/a in 2023 –planned MGA production will be small at closer to 150,000 t/a P_2O_5. This would be comfortably absorbed by Western Europe's current import demand. However, the company anticipates a "protracted" process for acquiring environmental permits as well as technical challenges in handling high chloride levels. The company estimates the project will incur a total capital expenditure of around $1 billion.

ALGERIA

Phosphate project to be fast tracked

Algeria's President Abdelmadjid Tebboune has urged for the fast-tracking of three key mining projects aimed at bolstering the country's economy beyond oil and gas exports. The Algeria Press Service (APS) says that during a cabinet meeting, Tebboune called for the swift completion of the Gara Djebilet iron ore mine, the zinc and lead mine in Valley Amizour, and the phosphate mine in Bilad El Hadba. Bilad El Hadba, located in Tebessa, is projected to produce over 6 million t/a of phosphate rock. A railway line currently under construction will link the mine to the mining network, enabling the transport of over 10 million t/a of phosphate each year. The project is expected to generate $2 billion in annual revenues and approximately 14,000 jobs. ■

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People

Metso has appointed **Sami Takaluoma** the company's new president and CEO, effective from November 1, 2024. Metso's outgoing president and CEO, **Pekka Vauramo**, will continue with the company as per his contract until the end of 2024, to ensure a smooth transition of responsibilities. Sami Takaluoma has been with Metso since 1997 and has led Metso's Services business area since 2021. He has been a member of Metso's Leadership Team since 2017.

Kari Stadigh, chair of Metso's board of directors, emphasised Takaluoma's extensive experience with Metso's businesses and customer industries in their selection. "Sami has done an excellent job in leading the businesses and as a member of the Leadership Team over the past seven years. Under his leadership, Metso's services and consumables businesses have grown and created significant value, especially after the merger of Metso and Outotec. The board is convinced that Sami is the right choice to lead Metso into its next phase. On behalf of the entire board, I would also like to extend our thanks to Pekka Vauramo, who is now stepping down from his role as president and CEO of Metso as earlier agreed. Under Pekka's leadership, Metso has evolved into an even stronger company, with a significantly enhanced culture and improved customer satisfaction, and its profitability has been clearly raised to a new level. We wish Pekka all the best and success in his new phase of life," Stadigh continued.

Sami Takaluoma said: "I would like to warmly thank the board for the opportunity to lead this great company. Having had the privilege of working for Metso for 27 years, I can confidently say that I know the company and understand our potential. With Metso's long history and strong foundation in the aggregates and mining markets, we are excellently positioned to achieve industry leadership. I eagerly anticipate embarking on this journey to deliver even greater value to our customers and stakeholders, alongside my talented and dedicated colleagues."

Strathcona Resources Ltd has announced the retirement of **Rob Morgan** as President and CEO, effective October 31, 2024. "On behalf of the board of directors, I would like to sincerely thank Rob for his leadership at Strathcona," commented Adam Waterous, Strathcona's executive chairman, adding, "Over the past seven years, Rob has overseen Strathcona's transformation from a junior oil company with approximately 17,000 barrels per day of production, 130 million barrels of proved plus probable reserves and fewer than 200 employees, into Canada's fifth largest oil producer, growing production approximately 11-fold, reserves 20-fold, and our employee base 4-fold. Rob has been a first-class partner to Waterous Energy Fund from the beginning, and we wish Rob all the best in his future."

Rob Morgan added, "It has been an honour to help lead Strathcona through a period of unprecedented growth, and I would like to thank Strathcona's Board of Directors, shareholders and employees for their faith and support the past seven years. I am excited to hand the reigns to Strathcona's next generation of leaders, who I am confident will take the company to new heights."

Going forward, Strathcona's leadership structure will transition from a single, functionally organized executive team working across Strathcona's entire asset base, to four focused business units – SCR Cold Lake, SCR Lloydminster Thermal, SCR Lloydminster Conventional, and SCR Montney – each with their own president and accompanying management team.

Neste has appointed a new leadership team as of today, including: Heikki Malinen, who in addition to his president and CEO role, takes the lead of Neste's Renewable Products business area. Markku Korvenranta continues in the leadership team and has been appointed executive vice president, Oil Products, and Chief Operating Officer (COO) of the company. Eeva Sipilä has been appointed Chief Financial Officer (CFO) and she will start at Neste no later than 1 May 2025. Until then Anssi Tammilehto, Vice President, Investor Relations, will act as interim CFO. Hannele Jakosuo-Jansson continues in the Leadership Team as Executive Vice President, People & Culture. ■

Calendar 2024/2025

NOVEMBER

11-14

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

14

European Sulphuric Acid Association General Assembly, MADRID, Spain
Contact: Francesca Ortolan, Sector Group Manager, Cefic
Tel: +32 499 21 12 14
Email: for@cefic.be

FEBRUARY 2025

5-7

SulGas Conference 2025, MUMBAI, India
Contact: Conference Communications Office, Three Ten Initiative Technologies LLP
Tel: +91 73308 75310
Email: admin@sulgasconference.com

24-27

75th Laurance Reid Annual Gas Conditioning Conference, NORMAN, Oklahoma, USA
Contact: Lily Martinez, Program Director
Tel: +1 405 325 4414
Email: lmartinez@ou.edu

MARCH

31 – APRIL 2

CRU Phosphates+Potash Expoconference, ORLANDO, Florida, USA
Contact: CRU Events
Tel: +44 (0) 20 7903 2444
Email: conferences@crugroup.com

APRIL

7-9

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

8-10

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

28 – MAY 2

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

JUNE

6-7

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

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- Hydrogen: Explore its role in energy and future fuels
- Urea + Methanol: Key advancements in operations, catalysts and technology
- Synthesis Gas: Innovations in generation and purification
- Nitric Acid + Nitrogen Fertilizers: Operations, technology, and environmental compliance

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The merchant market for sulphuric acid

Short term supply constraints are dominating acid markets at present, but increasing smelter production across Asia may lead to oversupply in the longer term.

The merchant market for sulphuric acid remains a relatively small slice of the overall acid market. In 2024 it is estimated to be 22.3 million t/a out of a total acid consumption of 306 million t/a. As Figure 1 shows, fertilizer production remains the largest consumer of sulphuric acid globally, driven by phosphoric acid's use in phosphate fertilizers. Morocco, China, and India are key players, with Morocco's OCP (Office Cherifien des Phosphates) investing heavily in sulphuric acid production to support its phosphate industry. A recovery in global phosphate demand has accelerated sulphuric acid consumption, a trend expected to continue as agricultural demands for fertilizer intensify worldwide.

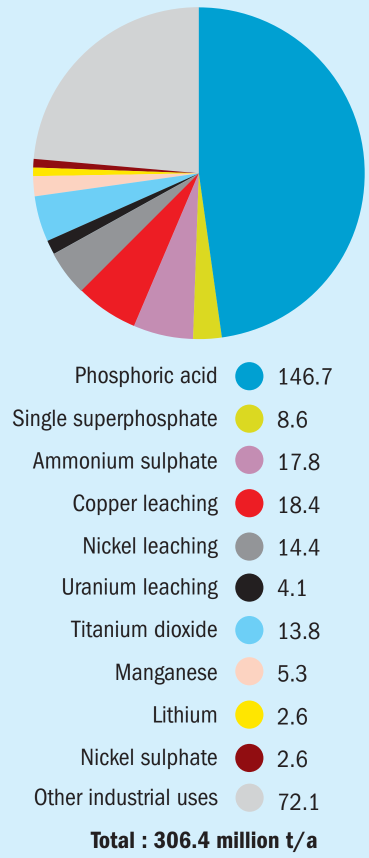
Batteries and metal processing

Demand for sulphuric acid is expanding in the battery and metal processing sectors, especially in the production of battery materials such as nickel and lithium, essential for electric vehicles (EVs) and energy storage. Indonesia, for example, is experiencing a surge in demand for sulphuric acid, supporting its nickel leaching projects. Additionally, increasing production of lithium-ion batteries across Asia, particularly in China, is bolstering sulphuric acid demand.

Industrial applications

Beyond fertilizers and batteries, sulphuric acid serves in various industrial applications, including petroleum refining and chemical synthesis. Industrial sectors in Asia, especially in China and India, are rapidly growing, thereby supporting consistent sulphuric acid demand over the coming years.

Fig. 1: **Sulphuric acid demand by end-use, 2024**

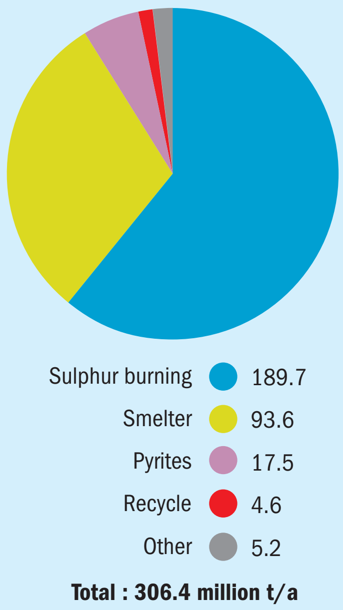


Source: CRU

Supply dynamics

Figure 2 shows sulphuric acid supply by source. In spite of some residual pyrite roasting, mostly in China, the supply of sulphuric acid is essentially influenced by the availability of smelter by-product acid and output from sulphur-burning facilities. Smelter acid production has been constrained this year by the availability of copper concentrates, but acid from sulphur burning supplements the demand shortfall. Notable supply developments include:

Fig. 2: **Sulphuric acid supply by source, 2024**



Source: CRU

Growth in smelter capacity

New smelter projects in Asia, primarily in China and Indonesia, are expected to significantly impact global supply. India's Adani Mundra smelting plant and Indonesia's Freeport smelting project in Gresik, expected to operate at full capacity by late 2024, will increase regional supply and reduce import dependence. While these expansions bring more supply, a key constraint remains copper concentrate availability. There is a projected copper concentrate deficit through 2025, which may limit sulphuric acid production from smelters.

Sulphur-burning capacity

Sulphur-burnt acid production, particularly in Morocco and China, is set to rise to meet fertilizer sector demands. Sulphur-

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burning facilities offer a reliable, though more costly, production method compared to smelter by-product acid. Morocco's OCP complex at Jorf Lasfar, for example, is increasing its sulphur-burning capacity by 1.8 million t/a. As sulphur-burnt acid costs remain high, its competitive position is challenged when compared to the more economical smelter by-product acid, especially in regions with higher transportation costs, such as Europe and Brazil. However, the market is seeing increased supply integration with sulphur burning acid production being built at consuming sites in order to gain control over supply and costs. This is leading to a contraction in the merchant market overall and may contribute to lower prices next year.


PHOTO: PT SMELTING

PT Smelting's acid plant expansion, Gresik, Indonesia

Recycling and other sources

Recycling and pyrites provide minor contributions to the global sulphuric acid supply. However, pyrites-based output, particularly in China, is anticipated to decline, partly due to environmental restrictions. Recycling is a stable but limited supply source, with its impact concentrated in highly industrialised regions.

Regional market dynamics

Each region contributes uniquely to global demand and supply dynamics, with regional trends highlighting differences in sulphuric acid production methods, trade balances, and sector-specific demands:

Asia

China, the largest consumer and producer of sulphuric acid, is shifting towards meeting domestic demand with increased smelter acid production while reducing export volumes. With exporters changing to mostly smelter-based acid, this may limit China's ability to react to changing acid prices.

There is an oversupply risk in Asia by 2025 as regional projects ramp up, with India and Indonesia also becoming significant producers. Indonesia's sulphuric acid demand is closely tied to its nickel projects, which are essential for EV battery manufacturing. The country's HPAL projects, like PT Lygend, are projected to add 11.4 million t/a of sulphuric acid production by 2028. China is forecast to add 3.7 million t/a of sulphur burning acid production over the same period, and increases in domestic operating rates may add another 3 million t/a of effective supply.

> **"The market is seeing increased supply integration, with sulphur burning acid production being built at consuming sites in order to gain control over supply and costs."**

Europe

Europe's sulphuric acid market has been relatively tight due to lower output from domestic smelters. Demand is stable, primarily for industrial and agricultural uses, while prices are high compared to Asian benchmarks due to transport costs. European supply challenges are compounded by smelter maintenance and limited expansion plans. Nevertheless, a recovery in smelter supply is expected to boost supply to 21 million t/a by 2027. Export volumes will decline slightly, from 3.2 million t/a to 2.7 million t/a by 2028.

Americas

North and South America exhibit slower demand growth. US sulphuric acid consumption remains stable, with modest growth tied to fertilizer and industrial use. By 2025, supply growth is anticipated due to the Southern States Chemical sulphur burner in Georgia and expanded production at Rio Tinto's Garfield smelter.

Brazil and Chile are notable in South America. Chilean demand has been impacted by mine closures and reduced copper-based consumption, though a rebound is expected in 2025 as mining activity resumes. Brazil's market outlook is mixed, with some growth in fertilizer production but slower industrial demand.

Africa

Morocco's sulphuric acid demand is closely linked to OCP's phosphate production expansion. Phosphate demand growth drives Morocco's sulphuric acid consumption, making it a key market in Africa. Morocco's imports surged in early 2024 as its domestic sulphur-burning facilities

Sulphuric acid rail cars

were expanded. There will be increased domestic production by 2025, potentially reducing the need for imports.

Australia

Australia faces unique supply challenges, with the closure of BHP's Nickel West smelter at Kalgoorlie in 2024 significantly reducing sulphuric acid availability. This loss is expected to turn Australia into a net importer of sulphuric acid, with imports rising as regional sources are sought to meet industrial demand, especially for nickel processing.

Pricing trends and trade dynamics

Sulphuric acid prices reached higher levels in 2024, their highest levels for two years, influenced by supply tightness and increased transportation costs. Benchmark prices for sulphuric acid in regions such as Brazil, the U.S., and Europe have risen, with Brazilian prices climbing from $125/tonne in April to $149/tonne by August.

Freight costs have kept European prices at a premium relative to Asian f.o.b. markets. Despite increased freight costs in the Pacific, the Atlantic market maintains higher premiums due to tighter supply. However, a gradual price correction is expected, beginning in late 2024 or early 2025 as supply pressures ease. Increased smelter production capacity in Asia, specifically in India and Indonesia, is expected to contribute to market oversupply. By 2028, prices are likely to align more closely with sulphur-burnt acid production costs, leading to a balanced supply-demand dynamic.

China's role as a sulphuric acid exporter is diminishing as domestic demand grows and export volumes are reduced. Meanwhile, India and Indonesia are increasing their exports, with the new smelting capacity targeting both domestic and international markets.

A reduction in annual import requirements is expected in Morocco in 2025, but major importers in India, Chile, SE Asia and the USA are all expected to maintain a stable import demand. A change in the structure of Chinese acid exporters, from predominantly sulphur-burnt acid to predominantly smelter acid, has shifted the market's ability to respond to import demand weakness. Although moderated from recent highs, freight rates will continue to maintain larger (than historically typical) price gaps between South American delivered markets and East Asian origins into 2024/25.

Outlook

The sulphuric acid market outlook to 2028 presents both growth opportunities and risks:

- Oversupply: The expected growth in Asian smelter capacity may push the market toward oversupply by 2025. This would lead to increased competition among producers, especially those reliant on sulphur-burnt acid production, which is costlier than smelter by-product acid.
- Copper concentrate shortages: The availability of copper concentrates is a major concern. A deficit in copper concentrates is expected to limit smelter acid production, particularly in China, which could constrain supply and sustain price premiums in some regions.
- Sulphur price volatility: The cost of sulphur, the primary input for sulphur-burning acid, is projected to increase, adding to production costs. This volatility could affect pricing strategies, particularly for producers in regions heavily reliant on sulphur-burning processes.
- Regulatory and environmental factors: Environmental regulations, especially in Europe and China, may limit sulphuric acid production from pyrites and smelters, potentially constraining supply in regions with stringent environmental policies. Recycling initiatives may expand but are not expected to meet the total demand requirements.
- Battery metal demand: Growing demand for battery metals such as nickel and lithium will likely absorb some of the excess sulphuric acid production. ■

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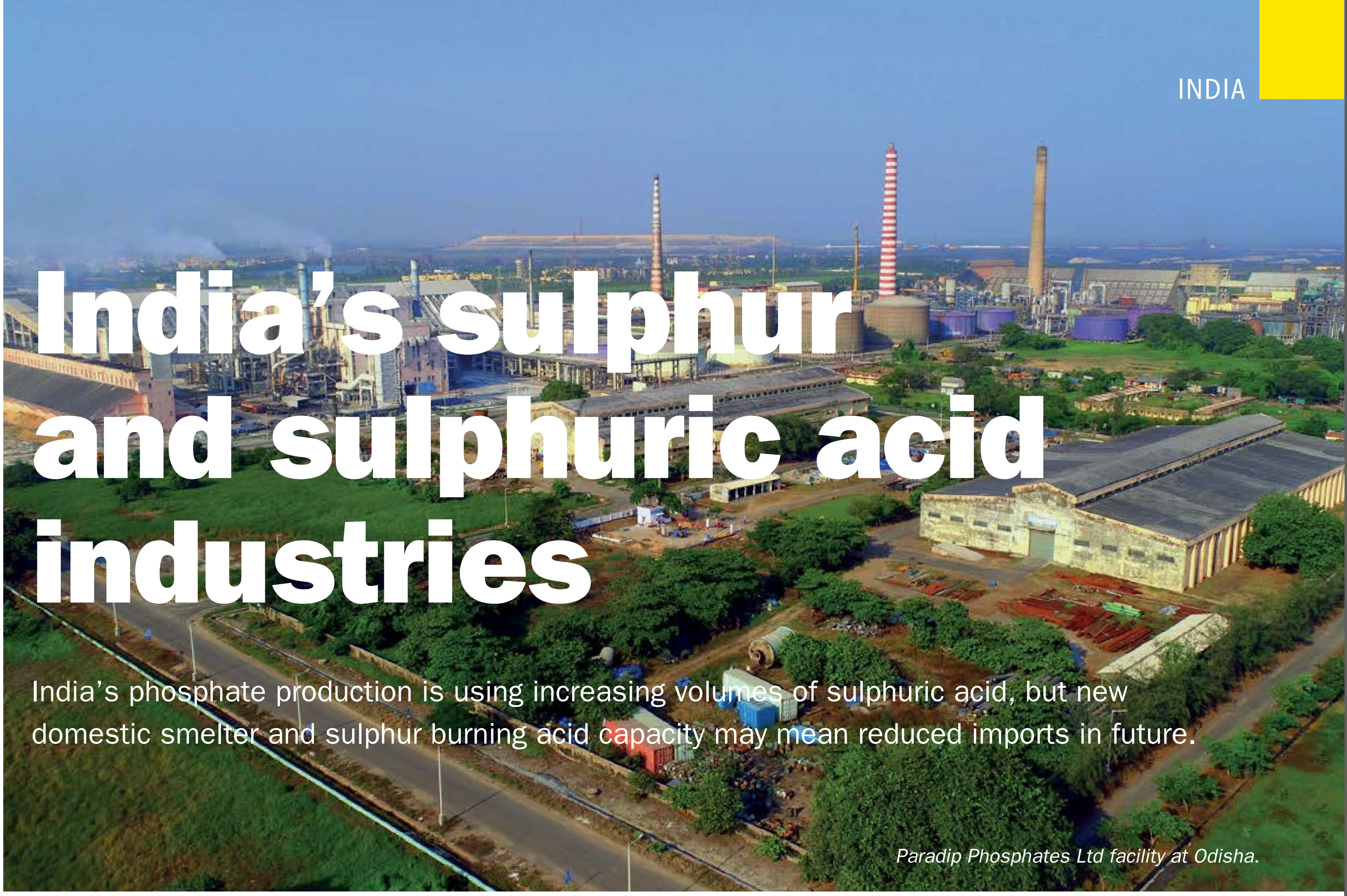

PHOTO: PPL

India's sulphur and sulphuric acid industries

India's phosphate production is using increasing volumes of sulphuric acid, but new domestic smelter and sulphur burning acid capacity may mean reduced imports in future.

Paradip Phosphates Ltd facility at Odisha.

India is now the world's fifth largest economy and the second largest country in the world by size of population, and both of these indicators continue to grow. GDP grew by 6.7% year on year for 2Q 2024, and is projected to be 7.0-7.2% for the 2024-25 fiscal year, making it one of the stars of the global economy now that China's economic growth has stalled. As these growth rates continue, by 2030, India is projected to be the world's third largest economy after the US and China. However, rising population – India is projected to overtake China some time in the next decade – mean that there is also rising demand for food and fertilizer.

Phosphates

Phosphate availability is a key factor for India's agriculture. India has a significant domestic finished phosphate industry but little domestic phosphate rock mining. Consequently the country is one of the most important importers of phosphate rock and phosphoric acid, and the largest importer of processed phosphates like DAP.

India's phosphate consumption was 7.9 million t/a P_2O_5 for the fertilizer year 2022-23, according to the Fertilizer Association of India, part of a steady increase over the past few years. This included 4.9 million t/a P_2O_5 of MAP and DAP, 0.8 million t/a P_2O_5 of single superphosphate (SSP), 1.7 million t/a P_2O_5 of triple superphosphate (TSP) and 2.6 million t/a of nitrophosphates and NPK fertilizer. Domestic phosphate fertilizer production was 5.0 million t/a P_2O_5, including 2.2 million t/a (P_2O_5) DAP and 1.1 million t/a P_2O_5 of SSP. Imports of DAP ran at 6.6 million t/a (tonnes product).

However, more recently high phosphate prices, especially for DAP, have dramatically impacted upon domestic demand, with a lack of availability from Russia and China. India runs a nutrient-based fertilizer subsidy (NBS) scheme and mandates maximum retail prices (MRP) for key fertilizers, and the government has tried to boost NPS rates for phosphates to make imports more affordable, but even with drawdowns of domestic stocks, DAP remains expensive for farmers. Between January and July, DAP imports plummeted 51% year on year, while domestic production declined 19%, leading to a steep 48% decrease in stocks. Negative margins have kept major buyers away, pushing farmers and importers to seek alternatives.

The ongoing supply crunch has prompted India to seek alternatives to DAP, bringing into the spotlight NP/NPKs, SSP and TSP. There has been renewed interest in TSP, particularly from Moroccan producer OCP. In the first half of this year, OCP sold around 30,000 tonnes of TSP to India, marking a tentative re-entry into the market, and OCP later agreed to supply 200,000 tonnes of TSP at $455-460/t c.fr for September loading. However, a large scale shift to TSP would require significant effort in terms of education, distribution, and adjustments to the NBS scheme to make TSP more attractive and viable for both importers and farmers. Also, the existing infrastructure, distribution networks, and farmer familiarity are all geared towards DAP and other established fertilizers.

Sulphur supply

India's domestic sulphur supply comes almost exclusively from oil refining. India's refining capacity is currently 5.1 million bbl/d, but this is expanding, and is expected to reach 6.4 million bbl/d by 2030 and 7.7 million bbl/d by 2040, from its present 5 million bbl/d. The rapidly growing economy and rising population are contributing to increased demand for liquid fuels. The Indian government has authorised several brownfield projects which are expected to add 1 million bbl/d of additional capacity at existing refineries by 2025, and there are also two major new greenfield refineries under development to add a further 1.2 million bbl/d of capacity. Indian fuel sulphur standards have also moved to a Euro-VI level of 10 ppm permitted sulphur, meaning that more sulphur is being recovered from that throughput. The combination of new capacity and tighter fuel standards mean that Indian refinery sulphur output has virtually doubled over the past decade, increasing

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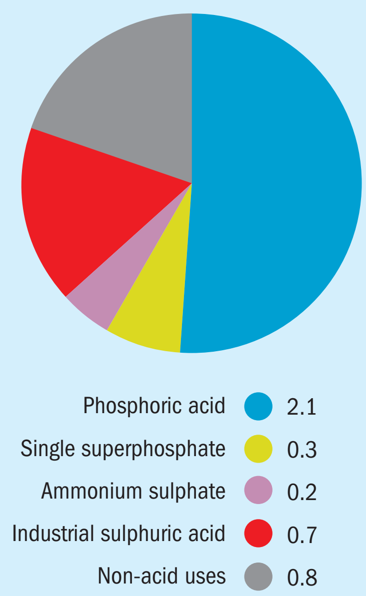
from 2.1 million t/a in 2014 to an estimated 3.9 million t/a in 2024.

Indian sulphur consumption runs at just over this, and is expected to reach an estimated 4.1-4.3 million t/a in 2024, an increase of 400,000 t/a compared to 2023. But while this makes India a slight net importer of acid, the country is in fact both a large exporter and importer of elemental sulphur, with exports mainly from west coast refineries and imports arriving on the east coast to feed phosphate production. Exports have been on a declining trend, dropping 7% in 2023 to 1.4 million t/a, and are expected to be lower still this year at around 1.2 million t/a. Imports meanwhile have been on an increasing trend, rising to 1.63 million t/a in 2023, but they have been relatively subdued in the early part of this year, with figures for Jan-April showing only a 1% increase year on year to 400,000 tonnes, and overall Indian sulphur imports for 2024 are expected to be lower at around 1.34 million t/a. Most of these arrive via the port of Paradip, near to phosphate manufacturer Paradip Phosphates Ltd (PPL). Paradip accounted for 66% of imports in 2023, up 23%. Domestic supply is expected to increase by 140,000 t/a this year, as production ramps up at the Indian Oil Company's (IOC) Panipat refinery project. Most Indian acid producers import sulphur from the Arabian Gulf region. The major exporters of sulphur into India are Abu Dhabi, Qatar, Oman, Japan, Singapore, Saudi Arabia, Kuwait and Bahrain.

Fig. 1: **Indian sulphur consumption by end use, 2024 (est), million t/a**



Source: CRU

Consumption

As Figure 1 shows, India's consumption is mostly for phosphate fertilizer production – the phosphoric acid section which is the largest slice of consumption is mostly for domestic mono- and diammonium phosphate (MAP/DAP) and triple superphosphate (TSP) production, with single superphosphate (SSP) adding another 330,000 t/a of sulphur demand. New sulphur burning acid plants for phosphate producers will see demand increase. Coromandel International Ltd (CIL) started its new sulphur burner capacity in late August 2023, adding 200,000 t/a, and a new burner capacity at IFFCO was inaugurated in May 2024, also with a capacity of 200,000 t/a. Over the medium term, supply is not expected to be able to meet the sustained growth in demand, leading to a continuing increase in import requirements, forecast to reach 2.1 million t/a by 2028.

Sulphuric acid

India has over 70 sulphuric acid plants, although many of them are extremely small and associated with small scale chemical production. India's sulphuric acid production is split between sulphur burning acid plants which run on the domestically generated and imported sulphur, and several metallurgical acid plants associated with base metal smelting; copper, zinc and lead. On the metallurgical acid side, Hindustan Zinc Ltd (HZL) is the largest producer, with production from its lead smelter at Chanderiya, and zinc smelters at Debari and Dariba. Hindustan Copper operates two more acid plants at Khetri and Ghatsila, and Hindalco has three sulphuric acid plants at its Dahej copper smelter at Birla.

On the sulphur-burning acid side, most of the plants are associated with downstream phosphate fertilizer production. The Indian Farmers Fertilizer Cooperative (IFFCO) at Paradeep in Orissa is the largest. Other major producers include Paradeep Phosphates Ltd (PPL), Gujarat State Fertilizers & Chemicals Ltd (GSFC), Fertilizers and Chemicals Travancore (FACT) and Coromandel Fertilizers. There is also acid capacity at Mangalore Chemicals and Fertilizers (MCFL) and Khaitan Chemicals and Fertilizers. Outside of fertilizer production, there are some smaller sulphuric acid plants associated with the chemical industry.

Indian acid production was 11.4 million t/a in 2023, a level which has been relatively stable since the closure of the Sterlite copper smelter in 2018 (see below). Consumption runs slightly higher than this at 13.3 million t/a in 2023, leading to a deficit of 1.9 million t/a which is made up by imports of sulphuric acid. Hence as well as producing their own acid from sulphur burning, many major phosphate producers also import sulphuric acid directly. Major acid importers include Coromandel, IFFCO, Greenstar, PPL, FACT and MCFL.

New acid capacity

As noted above, there are new sulphur burning acid plants which are continuing to expand Indian acid production. CIL started its new 500,000 t/a sulphur burner plant in late August 2023, and the company also announced in April 2024 an investment on a new phosphate plant at Kakinada, with an acid capacity of 600,000 t/a, which is expected to be commissioned in 2026. IFFCO reportedly commenced operations at its sulphuric acid plant in Paradeep in May with a total acid capacity of 600,000 t/a, while Gujarat State Fertilizers and Chemicals (GSFC) is expected to commission its sulphuric acid plant at Sikka unit in 2025 and reach a full capacity of 600,000 t/a by 2026. PPL will commission its sulphuric acid plant of 500,000 t/a between 2024-25.

Adani

As well as sulphur burning acid capacity, there is a new major copper smelter in India which will add another 1.5 million t/a of acid capacity. The Kutch Copper smelter, owned by Adani Enterprises Ltd, started operations in March 2024 at Mundra, with the capacity to produce 500,000 t/a of copper in its first phase at a cost of $1.2 billion. A second phase which will double capacity to 1.0 million t/a of copper and 3.0 million t/a of acid is under development, according to the company, and is expected to be completed in 2029. India's increasing demand for copper is being driven by investment in renewable energy, electric vehicles, charging infrastructure, and the development of power transmission and distribution networks.

Sterlite

Finally, mention must be made of the ongoing saga of the Sterlite Copper smelter in Tuticorin. Sterlite, a wholly owned subsidiary of the Vedanta group,

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Table 1: **Indian sulphuric acid supply and demand, 2021-2028, million t/a**

Year	Demand	Supply (smelters)	Supply (sulphur burning)	Net imports
2021	13.1	2.4	9.2	1.5
2022	13.5	2.4	9.3	1.8
2023	13.3	1.9	9.5	1.9
2024	14.8	2.2	10.1	2.5
2025	15.2	3.1	9.9	2.2
2026	16.0	3.4	10.8	1.8
2027	16.8	3.8	11.5	1.5
2028	17.5	3.8	12.6	1.1

Source: CRU

operated what was then the largest smelter in India, and which produced around 1.2 million t/a of sulphuric acid, most of which went to the domestic fertilizer industry. Sterlite also had plans to double the smelter's capacity to 800,000 t/a. However, the smelter was closed in May 2018 after the plant's operating license was not renewed by the pollution control board of Tamil Nadu province due to environmental concerns which had driven a huge local protest movement, leading to riots in which there were a number of fatalities. That ruling was overturned by the Indian environmental court, the National Green Tribunal (NGT), which would have allowed the smelter to recommence operation, but this decision was itself appealed by the Tamil Nadu regional government, and the case ultimate ended up in India's Supreme Court. After several years of legal arguments, in February 2024 the Supreme Court ruled that the smelter should remain closed, citing "serious environmental violations and repeated breaches". The removal of the smelter not only turned India from a net copper exporter into an importer, but also created havoc with the domestic sulphuric acid market. Sterlite has presented a petition for review, but it took a $90 million writedown to its Q2 accounts over the court decision, and the smelter looks to be closed permanently now.

Imports to fall slightly

As Table 1 shows, acid supply from both smelters and sulphur burning capacity is increasing rapidly, and while demand, mostly from the phosphate sector, is also increasing, by about 4.2 million t/a over the period 2023-2028, additional domestic availability of acid in India is expected to increase production by about 5 million t/a over the same period, reducing acid import requirements over the coming years, with net imports for 2028 projected to be down to 1.1 million t/a. However, actual import volumes are expected to be maintained above 1.7 million t/a, as the new smelter capacity will likely export additional volumes. ■

The market for ammonium sulphate

Continuing growth in Chinese ammonium sulphate production is leading to a continuing flood of exports, as greater awareness of the utility of sulphur as a fertilizer leads to increasing global demand.

DOMO Chemicals caprolactam plant at Leuna, Germany

PHOTO: DOMO

Ammonium sulphate (AS) remains a popular fertilizer for its combination of nitrogen and sulphur nutrients. Indeed, the growing awareness of sulphur deficiency in soils, caused by a switch away from sulphur-containing fertilizers such as AS and single superphosphate (SSP) towards urea and mono/di-ammonium phosphate (MAP/DAP), and the reduction in deposition of sulphur on soils from sulphur dioxide pollution in the air as power plants and car exhausts become cleaner, mean that the soil nutrient sulphur requirement is growing. This in turn is leading to a resurgence in popularity for ammonium sulphate as a fertilizer and its use growing by about 3% year on year, faster than overall growth in fertilizer demand.

Production

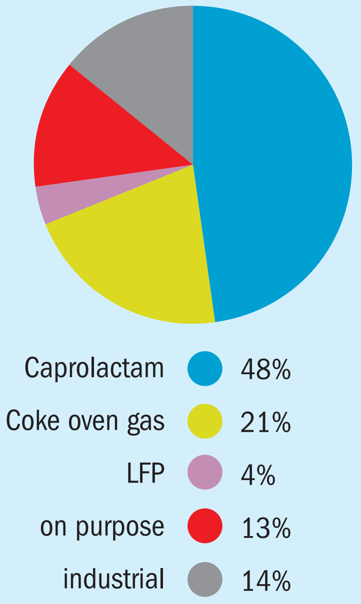
Ammonium sulphate production worldwide was 32.5 million t/a in 2023. About half of all ammonium sulphate production (15.6 rolactam production (see Figure 1). One of sulphuric acid's prominent chemical uses is in the production of caprolactam, with ammonium sulphate generated as a by-product. The switch of global fibre production to China has led to a major increase in caprolactam production there, and concomitant demand for sulphuric acid.

Almost all (about 95%) of caprolactam is produced by reacting cyclohexanone (made from cyclohexane or phenol) with ammonia and sulphuric acid. Cyclohexanone oxime is converted to caprolactam via a process known as the Beckmann rearrangement, which occurs at 100°C in the presence of sulphuric acid. The oxime rearranges to become the lactam sulphate, which is then neutralised with ammonia, releasing the caprolactam with co-production of ammonium sulphate. The amount of AS generated depends upon the process. Earlier versions might produce up to 4.5 tonnes per tonne of caprolactam and consume relatively large volumes of acid, but more modern processes such as DSM's HPO process have managed to get this figure down to 1.5-1.8 tonnes of AS per tonne of caprolactam.

Other routes for production of AS are ammonia scrubbing of coke oven gas (about 6.7 million t/a in 2023), and as a by-product of lithium iron phosphate production (1.3 million t/a). Other industrial processes such as nickel pressure acid leaching, methyl methacrylate (MMA) and acrylonitrile production, and ammonia scrubbing of emissions from coal gasification or coal fired power stations, which collectively represent another 4.7 million t/a of production. The rest (4.1 million t/a) is on-purpose production; there was a resurgence for on-purpose production of AS in the early 2000s, mainly of higher grade product which can attract a premium price, and such developments are continuing, but on-purpose production of AS still accounts for only 13% of the industry.

Overall, the world consumes around 17 million t/a of sulphuric acid to make ammonium sulphate, or about 6% of all acid demand in 2023, with the lion's share of

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



Source: CRU

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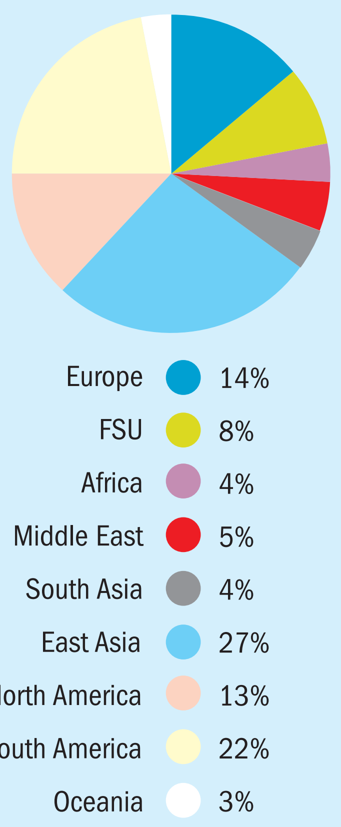
that coming from China, which consumed 6.9 million t/a of acid to make AS in 2023, or about 40% of production. Chinese AS production has risen because of a massive expansion in caprolactam production for synthetic fibres. China now represents around 60% of a total world caprolactam production of about 6.7 million t/a.

Consumption

Ammonium sulphate (AS) has historically been used mainly (95%) used as a nitrogen fertilizer and AS consumption accounts for about 5.7% of the global nitrogen fertilizer market – a share which fell to a low point around 2010, but which has since been climbing significantly. One of the main reasons for this is that it is now also increasingly valued as an important source of plant nutrient sulphur; AS has a high sulphur content in the sulphate form, making it readily absorbable by plants. It also has a low pH, making it suitable for alkaline soils. Outside of fertilizer use, industrial use of AS accounts for only about 5% of world consumption, in applications such as cattle feed supplements and a variety of small pharmaceutical and chemical uses.

Consumption of ammonium sulphate declined during the 1980s and 90s as other nitrogen fertilizers like urea and ammonium nitrate became preferred, due to AS's relatively lower nitrogen content, but the market moved back into growth in the 21st century, rising at 2.8% per year from 2000–2013, then dropping to 2.3% per year from 2013–2018, but the past few years have seen growth take off; AS consumption grew by 4.5% from 2022 to 2023, and it is forecast to top 5% this year. Demand is concentrated regionally; Southeast Asia, Latin America and Western Europe between them account for about 50% of world AS consumption. Figure 2 shows the regional breakdown of demand worldwide. The South American figure is dominated by Brazil, which represents two thirds of regional consumption.

Fig. 2: **AS demand by region, 2023**



Source: CRU

Going forward, AS is expected to continue to capture a higher share of world nitrogen fertilizer demand, because of its sulphur content. Brazil has been a major growth market for AS, where it is beginning to substitute for urea and ammonium nitrates. China has responded with a surge in compacted granule capacity to meet Brazil's requirements. China accounted for 95% of Brazil's total imports in 2023 which has pushed European and US exports to find new locations to sell to. The surge in Chinese supply arrivals has also cut the value of the granular premium in the Brazilian market. Indonesia has been a major user, though consumption dipped in 2022-23, and southeast Asia in general remains a major consumer, with consumption rising in e.g. Myanmar. Overall, southeast Asian demand is forecast to rise from 6.5 million t/a in 2023 to 7.6 million t/a in 2028.

China dominates trade

The surge in the Chinese caprolactam industry (and indeed other industries) discussed earlier means that most new AS capacity growth over the past decade has occurred in China, and China is forecast to continue to account for the major growth in AS capacity over the next few years. Chinese AS capacity has grown from 6.0 million t/a in 2010 to 22.3 million t/a in 2023, with a further 6.0 million t/a of capacity expected by 2028, some from new caprolactam based production, but mostly from LFP battery production, offsetting a decline in coke over gas production as China shifts towards lower carbon methods of steel production. By 2028, China is expected to represent 42% of all AS production.

At the same time, Chinese domestic demand for AS is relatively small, mostly for some blended products, and urea remains the preferred nitrogen fertilizer for Chinese farmers. This means that more than 85% of Chinese production is exported, and as a result, Chinese supply represents about half of all internationally traded AS. China exported 13.8 million t/a of AS in 2023, up from 8.7 million t/a in 2020, which has necessitated the hunt for new import markets.

Costs

A key determinant of AS demand is affordability. The cost of caprolactam production is mainly determined by the cost of benzene raw material to make phenol or cyclohexane precursor, but sulphuric acid and ammonia prices, energy costs, and the potential netback in terms of ammonium sulphate sales all have a bearing on production cost. Thus while AS production from caprolactam is involuntary, the AS market can nevertheless feed back into whether it is profitable to operate caprolactam capacity. AS tends to sell at a slight premium to per tonne nitrogen prices of other fertilizers due to its sulphur content. Nitrate prices in general are trending downwards at present, while sulphur and acid prices are rising. Prices at port for Chinese crystalline AS are expected to average $157/t f.o.b. in 2024 Q3 and follow a similar increasing trend to the end of 2024.

The effect on sulphur

As noted earlier, AS co-/by-production from caprolactam is in effect an index of sulphuric acid consumption in the process, with more modern processes requiring less acid. Most of the new plants in China use either ammoximation or HPOplus technology, both of which produce about 1.5 tonnes of AS per tonne of caprolactam, and consume slightly less than that in terms of tonnes H_2SO_4 (100%). Even so, the same trends are visible in acid consumption as in AS production - most growth of acid demand from caprolactam production this century has been and is likely to be in China. While Chinese consumption of sulphuric acid continues to be mainly for fertilizer, caprolactam has contributed to the boost to Chinese acid consumption provided by industrial uses, as our article elsewhere in this issue discusses. ■

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Industrial demand for sulphur dioxide

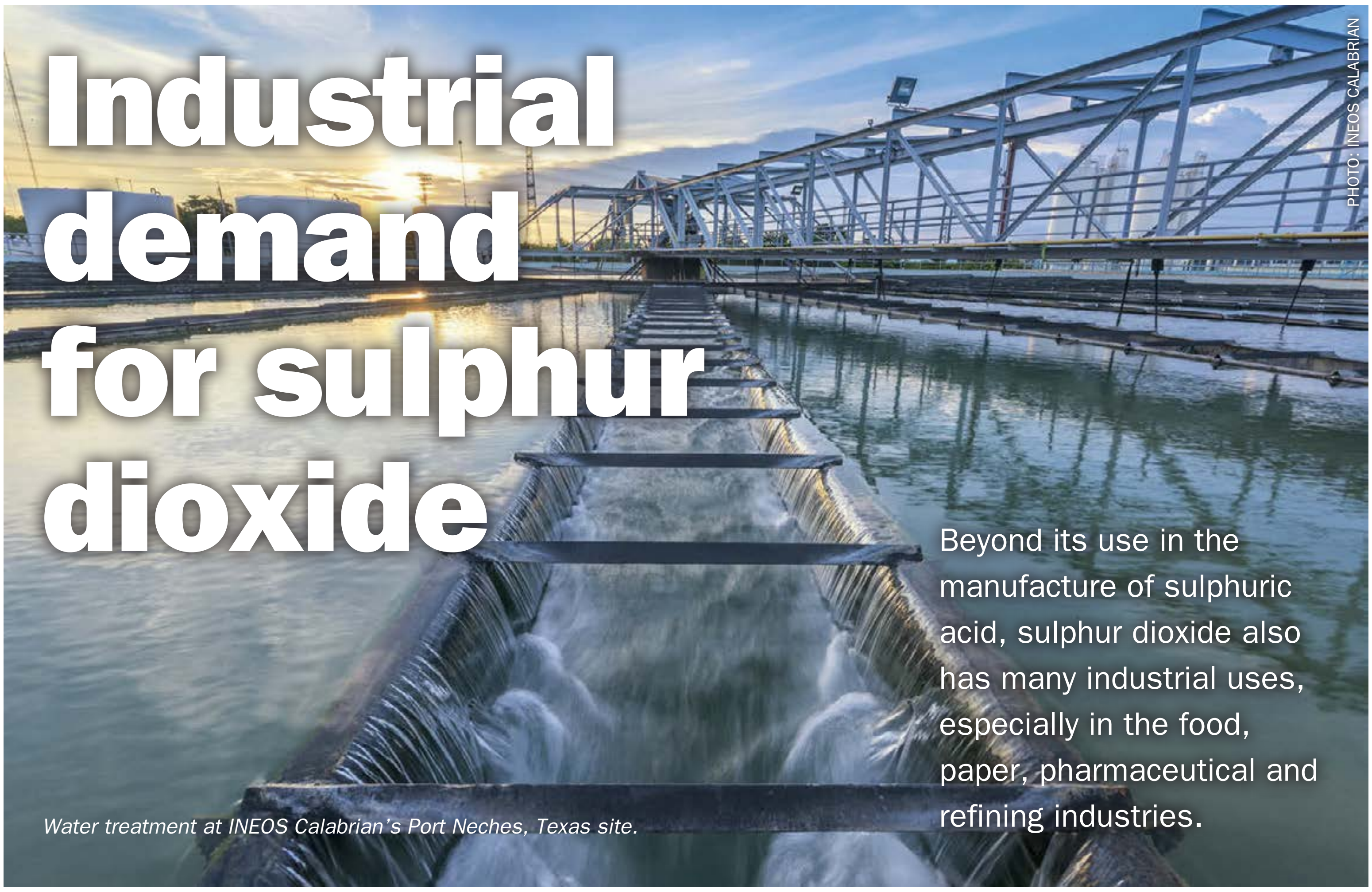

PHOTO: INEOS CALABRIAN

Water treatment at INEOS Calabrian's Port Neches, Texas site.

Beyond its use in the manufacture of sulphuric acid, sulphur dioxide also has many industrial uses, especially in the food, paper, pharmaceutical and refining industries.

Sulphur dioxide, SO_2, is mainly an intermediate in the sulphur industry; in sulphur-burning acid plants, it is the first step from combustion of elemental sulphur, and thereafter is further oxidised to SO_3 and converted to oleum. It is also, of course, a major by-product of the roasting of sulphide ores in the metals industry, from which sulphuric acid can be produced from pyrites or copper or nickel sulphides.

However, it does also have many diverse uses in its own right beyond simply the production of sulphuric acid, and so there is a relatively much smaller but nevertheless still significant market for liquid SO_2, with a number of plants around the world dedicated to the production of it.

Production

While SO_2 can in theory simply be extracted from a process stream at any sulphuric acid manufacturing facility, the requirements of the chemical industry are generally for extremely high purity product (>99.9% purity), and this necessitates extra clean-up steps. Most plants are based on burning of sulphur, either with air or, for example in Ineos Calabrian's SO2Clean process, with pure oxygen, and some are dedicated production sites, though there is some production from metallurgical off gas SO_2, for example by Boliden at its smelters in Scandinavia, and at Vale's smelter in Sudbury, Ontario, Canada, although this method is relatively under-used as metallurgical off-gas requires greater treatment to produce SO_2 of the required purity.

In a sulphuric acid plant, liquid sulphur dioxide can also be recovered as a side stream by partial condensation from the sulphur dioxide-rich gas stream that forms the feed gas stream to the acid plant, as described by Hugo Petersen at this year's Sulphur+Sulphuric Acid Conference. It is taken from downstream of the waste heat boiler after the sulphur furnace, or after the drying tower on a wet gas plant, and then cooled by exchange with the SO_2 plant tail gas followed by mist filtration to remove any traces of sulphuric acid. Refrigerated cooling down to -65 °C results in the condensation of much of the sulphur dioxide. This allows for process heat from sulphuric acid production to be recovered elsewhere in the process and can generate synergies in production.

> **“In a sulphuric acid plant, liquid sulphur dioxide can also be recovered as a side stream by partial condensation from the feed gas stream to the acid plant...”**

Alternatively, SO_2 can be made by reacting sulphur with sulphur trioxide (SO_3). This method is more complex than condensation-liquefaction but a very pure product is made and there is not the same cooling requirement. The process is normally integrated with the operation of a concentrated sulphuric acid plant producing oleum and SO_3. Molten sulphur is fed continuously with a stoichiometric amount of liquid sulphur trioxide into an agitated reactor containing hot oleum. The heat of reaction is removed by either cooling coils or jacket circulating water at ambient temperature. The gaseous sulphur dioxide produced passes through a bed containing solid sulphur to capture and convert accompanying sulphur trioxide vapour and any residual SO_3 is then removed in a 98% sulphuric acid absorber. The pure SO_2 gas stream is condensed and the liquid product pumped to storage.

Sulphur dioxide is also generated as a by-product from the manufacture of various petroleum additives, thionyl chloride, some detergents and other processes. It can be extracted by a solvent recycling process using methanol, ethanol, benzene, acetone or carbon tetrachloride.

Applications

Sulphur dioxide is used by a very wide range of industries and applications, including food and beverages, water treatment, disinfecting and fumigation; as a bleaching agent for oils and foods and a preservative for beer, wine, canned and bottled foods and dried fruits. It is also used in glass polishing and as an acidifying agent in float glass production, and for extraction of some metals from their respective ores.

Hydrosulphites

Hydrosulphites, of the form $X(S_2O_4).nH_2O$, where X tends to be an alkali metal like sodium, calcium or potassium, are used as reducing agents in various applications. In the textiles and other dyeing industries, sodium hydrosulphite, also known as sodium dithionite, can eliminate excess dye, residual oxide, and unintended pigments, thereby improving overall colour quality.

Bleaching agent

In the pulp and paper industry, sulphur dioxide is used to bleach wood pulp, and in the textile industry it is used to bleach wool and silk. The gas is effective in removing colour from materials without causing significant degradation, making it an important part of these manufacturing processes.

Food and agriculture

Sulphur dioxide is widely used as a preservative in food items such as dry fruits to maintain their colourful appearance and to prevent them from rotting. In the manufacture of wine, a small amount of sulphur dioxide is added to the must to destroy bacterial moulds and wild yeasts without harming the yeasts that produce the desired fermentation, and is the reason your wine label might say "contains sulphites". This is a large and growing segment of the SO_2 market.

Water treatment

Sulphur dioxide is used as a reducing agent in wastewater treatment. In water sulphur dioxide forms a soluble sulphite (SO_3^{2-}) which is able to react with chlorine compounds, such as hypochlorite, and so can be used to remove chlorine from water after treatment.

Metal refining

In mineral technology, sulphur dioxide and sulphites are used as flotation depressants for sulphide ores. In electrowinning of copper from leach solutions containing iron, sulphur dioxide is used to pre-reduce ferric to ferrous ions to improve current efficiency and copper cathode quality. Sulphur dioxide also initiates precipitation of metallic selenium from selenous acid, a by-product of copper metallurgy. In chrome waste disposal, it is used to reduce hexavalent chromium. It is also finding rapidly increasing use in battery recycling.

Oil industry

In the oil industry sulphur dioxide is used as a selective extraction solvent in the Edeleanu process, in which aromatic components are extracted from a kerosene stream, leaving a purified stream of saturated aliphatic hydrocarbons, which are relatively insoluble in SO_2. Sulphur dioxide acts as a catalyst modifier in certain processes for oxidation of ortho-xylene or naphthalene to phthalic anhydride.

Market size

Exact figures for use in these applications are hard to come by, as many users, especially in large scale applications, have taken to producing the SO_2 they require on-site by burning sulphur, as elemental sulphur is cheaper and more readily available than sulphur dioxide and is much easier to store and handle. Such captive production is often not reported or totalled in industry-wide figures. Likewise producers and distributors of liquid SO_2 can often be cagey about commercial contracts and volumes supplied. Some liquid SO_2 is also used for the manufacture of ultrapure sulphuric acid for the electronics industry, and so it can be classified as both part of the SO_2 or sulphuric acid markets. The best estimate is that the SO_2 market is currently around 1.1 million t/a worldwide, excluding pure sulphuric acid production.

> **"It has been heavily based in North America and Europe, but has seen a marked shift over the past two or three decades towards consumption and, increasingly, production in China and south and east Asia."**

Like many sectors of the chemical industry, traditionally it has been heavily based in North America and Europe, but has seen a marked shift over the past two or three decades towards consumption and, increasingly, production in China and south and east Asia, with North America and Europe accounting for about 30% of demand in 2020 and Asia-Pacif just over 50%.

This has led to a familiar pattern of industry consolidation in the traditional producing areas. In North America, Chemtrade has become an important producer and distributor, buying Rhodia's SO_2 interests in 2004 and the rights to the output from the Vale Inco smelter in Sudbury, Ontario in 2008, while it acquired the Marsulex SO_2 plant at Cairo, Ohio as part of its acquisition in 2011, and in January 2014 its acquisition of General Chemical gave it greater access to many downstream markets. Likewise INEOS's purchase of Calabrian in 2016 gave it a significant position in the SO_2 market in Europe and North America, with production at Port Neches, Texas, and more recently a new 40,000 t/a site at Timmins, Ontario, Canada. The US EPA puts US domestic SO_2 production at just under 100,000 t/a, and consumption at 146,000 t/a in 2023. As noted above, Boliden continues to be a major player in Europe using SO_2 from its smelters.

Food and agriculture, pulp and paper, and the industrial chemicals sector continue to be the largest areas of demand, accounting for an estimated 70% of all SO_2 demand, and all of these sectors continue to expand, driving increased consumption. ■

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Sulphur+Sulphuri

A report on CRU's annual Sulphur+Sulphuric Acid Conference, held in Barcelona, in early November.

CRU's Peter Harrison delivers the sulphur market presentation

CRU's 40th Sulphur+Sulphuric Acid Conference and Exhibition was held at the start of November this year, marking the first time that it has been run with Sulphur magazine back under the CRU banner. It was appropriate then that the welcome address was given by Sulphur's managing editor Lisa Connock, who remarked that this year has seen strong attendance, with more than 450 delegates representing over 200 companies from 43 countries.

Commercial session

The conference proper was preceded as usual by a morning of short Technical Showcase presentations by, amongst others, Wood Group, WIKA. Thermetrics, Howden Turbo, Wylton Chemical, Ohio Lumex, Düchting Pumpen Maschinenfabrik, and Academia Holtec, as well as two troubleshooting clinics, one on sulphur and the other on sulphuric acid.

The commercial session began with a keynote speech by Christian Sattler, director of the Institute of Fuels in Germany. His talk concerned sulphur's role in renewable energy pathways, and touched on the hybrid sulphur cycle, which can help convert water using high temperature heat, for example from a nuclear reactor, into hydrogen, reducing the mount of electrochemical energy required for electrolysis by 66% compared to cold electrolysis. He also mentioned SO_2 depolarised electrolysis, and sulphur based thermochemical cycles which could use sulphur as an energy carrier, using a sulphur splitting reactor – there was more detail on these in the institute's technical paper (see Sulphuric Acid Technology, below).

This was followed by a panel discussion on sulphur and sulphuric acid in the energy transition, chaired by Hannes Storch of Metso and also including Khalid Hamed Al-Ahmadi of Ma'aden, Lucretia Loescher of thyssenkrupp Uhde, Sascha Vukojevic of BASF, Graham Cousland from Begg Cousland Envirotec, and Francesca Ortolan from Cefic. BASF have reduced their CO_2 footprint by 60% since 1990 and want to reduce this by another 25% by 2030. The biggest source of emissions is power and steam production, and so they are shifting to making renewable electricity at sites globally. Lucretia Loeschler said that green molecules are three times more expensive than grey, so without guaranteed offtakers the economics do not work, and regulations are also important.

Sulphur markets

CRU's Dr Peter Harrison as usual gave the market overview. Sulphur prices have swung in 2024 from bust to boom. Having started 2024 relatively depressed at $70/t, but the past 2-3 months have seen prices take off. Sulphur has been undervalued relative to phosphates, but affordability has weakened as the sulphur price increases. New Middle Eastern supply is driving a surge in exports by 1.5 million t/a, but Chinese imports have risen by 800,000 t/a to 9.7 million t/a this year, and imports to Morocco and Brazil are also up. There have been stock drawdowns in Arabia and Kazakhstan which have masked relative undersupply this year, though a stock accumulation of 1 million t/a has happened in China.

On the demand side, metals markets are contributing to demand growth, with 3.2 million t/a of extra demand by 2029, mainly in southeast Asia, alongside 6.7 million t/a of demand from fertilizers, much of it in Morocco as well as Saudi Arabia and the US, and 1.7 million t/a from industrial uses. Supply growth is slow to 2027, when a new wave of capacity will hit with several large new projects coming on stream. Europe is seeing supply slow as refineries close or switch to bio-feeds, and by 2028 Europe will be a net sulphur importer. There is some substitution with acid replacing sulphur, but the continent may need more remelters. The US sulphur deficit is also widening as demand grows for lithium and phosphates and again falling output from refineries, with the US becoming a net importer from 2025, and imports increasing to 2 million t/a by 2029. In Central Asia, Kazakhstan has seen 1.2 million t/a of stock drawdowns in 2024 and probably another 600,000 t/a in 2025, but after that the stocks will be gone and the market will need to find a balancing factor from elsewhere. Middle East is driving supply availability, with Ghasha adding 3.4 million t/a, Shah 1 million t/a and Al Zour 1 million t/a of sulphur capacity. China is seeing imports fall as domestic supply increases – by 3.5 million t/a to 2028, while Indonesia is pulling in ever increasing imports. Overall, the market will be in deficit for the next couple of years, with higher prices, but will move back into balance by 2028.

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c Acid 2024

PHOTOS: CRU

The energy transition panel discussion. L-R: Khalid Hamed Al-Ahmadi (Ma'aden), Lucretia Loeschler (thyssenkrupp Uhde) Hannes Storch (Metso).

The presentation was followed by another panel discussion, on economics, strategy production etc, led by Peter Harrison and including Viviana Alvarado of CRU, Craig Jorgenson of TSI and Janne Loven of Boliden. Craig Jorgenson noted that the new lithium projects in Nevada – Lithium Americas at Thacker Pass and Ioneer at Rhyolite Ridge – will rely on sulphur burning to generate acid for their activities and may find sourcing sufficient sulphur a logistical challenge, especially given refinery closures in California and conversions to biofuel plants, reducing supply there by 400,000 t/a.

Sulphur technology

Lower carbon options are of course very much in vogue at the moment and several papers in the sulphur technology section looked at ways of reducing carbon footprint from a Claus reactor. H_2S is a potential source of hydrogen, and ITT examined ways of arranging an SRU to have an H_2S-splitting side stream to generate H_2. It can even use electrical heating using renewable energy for a carbon negative process. Worley Comprimo examined options for saving energy in a Claus reactor using lower reactor inlet temperatures, reduced co-firing and lower temperatures in the incinerator. Topsoe argued that a wet sulphuric acid (WSA) plant as an alternative to an SRU lowers carbon footprint considerably. IOCL's refinery at Haldia in India has recently made such a change.

Digitisation

As digitisation continues to make its way into sulphur plant operation, Worley Comprimo presented an analysis of factors to consider in developing a new 300 t/d sulphur facility in Europe using the probabilistic computer modelling features of their Indicatura software to determine life cycle cost and net present value, as well as factoring in CO_2 equivalent cost. The conclusion was that TOPCLAUS® is the most prominent technology in terms of revenue, but it also offers the highest potential for CO_2 emissions saving, while EUROCLAUS® (and SUPERCLAUS® + CSU for more stringent legislations) have the best results from the most conventional technologies.

Maire NextChem looked at digital process modelling to improve the efficiency of SRU operation, and Voovio Technologies examined enhanced reality technology for operator control systems to reduce human error and increase operator competence.

SRU operation

The SRU operations papers began with a design presentation by Bechtel which described best practice in designing SRUs, including strippers and tail gas treatment units.

Drawing on their experience of dealing with operator issues, Sulphur Experts said that optimising incinerator operation remains the best way of not only improving SRU operation but also making savings in fuel gas consumption and CO_2 emissions. Ben Spooner of Amine Experts meanwhile looked at preventing amine carryover from amine regenerators, using anti-foamers and foam testing of rich amine solutions.

Wood looked at considerations for reliability, safety, and operations responsibilities during extended downtime, and how best to look after a Claus plant that is expecting a prolonged period of being idled, while Rob Marriott of ASRL presented the results of a study into the presence of ammonia in SRUs with alkanoamines as a potential source. The study found that tertiary (MDEA) and secondary (DEA and DIPA) amines were more difficult to convert to NH_3 compared to primary amines (MEA and DGA). Through gradual accumulation, it is feasible that alkanolamine introduction to the Claus thermal reactor could lead to a buildup of ammonium salts.

AMETEK meanwhile looked at ways of measuring BTEX in process gas feeds to ensure complete destruction in the SRU (see article page 36).

Operator case studies

ADNOC Sour Gas described some of the issues experienced with their ground breaking Shah sour gas plant, including water carryover issues and challenges with steam quality in the waste heat boiler, corrosion in reheaters and the degassing contactor, and efficiency and emissions challenges with the incinerator. Kuwait Oil Co addressed sulphur-induced iron sulphide formation in effluent water treatment and injection facilities, examining both chemical and non-chemical ways of tackling the issue.

Sulphur handling

David Savage of Matrix PDM described Matrix's approach to safety in design for sulphur forming and handling facilities, particularly mitigation of the highest risk factor – airborne sulphur dust – via suitable levels of moisture content in the sulphur.

Marcus Weber of Fluor, meanwhile, looked at scaling up sulphur degassing systems to large scale sulphur recovery plants. Fluor's D'GAAS system can eliminate the need for a sulphur pit and its associated problems, and can be modularised for relatively easy scale up (see article page 40).

Finally, Sulphurnet noted that there is increasing sulphur coming from remelting of block and other long term storage at present, and examined some of the potential contamination issues and the challenges they could pose for SRU operation.


PHOTO: CRU

The exhibition hall

Sulphuric acid technology

Burning sulphur is a carbon free source of energy, and so perhaps unsurprisingly sulphur burning acid plants have become the focus of a lot of thinking on the energy transition, circular economy and the like. The sulphuric acid technology session began with presentations looking at decarbonisation and energy efficiency, including the work of the Deutsches Zentrum fur Luft und Raumfahrt and Grillo Chemicals (German Aerospace Centre – DLR) on using sulphur and sulphuric acid in decarbonisation. DLR is working on several pathways, including SO_2 depolarised electrolysis, which uses the SO_2 produced during sulphuric acid decomposition to produce hydrogen as well as fresh sulphuric acid as an additional product, and hence can be used for spent acid recycling while generating hydrogen at only 14% of the energy cost of PEM electrolysis. Another project uses mirrors to concentrate sunlight and convert it into high-temperature heat energy which can then be used to split sulphuric acid. The resulting fission products sulphur dioxide (SO_2) and water (H_2O) are the starting products for producing fresh sulphur – the latter can be stored or burnt in a gas turbine to generate electricity. This in turn produces sulphur dioxide (SO_2) as a fuel gas, which is fed into conventional sulphuric acid plants. This produces fresh sulphuric acid and a large amount of waste heat. The waste heat drives a steam turbine, which generates additional electricity. The fresh sulphuric acid is then available again for the splitting of sulphuric acid.

Nelson Clark of Clark Solutions looked at increasing heat recovery from acid plants by using a waste heat boiler instead of an acid cooler. Acid and water streams are kept separate in the SAFEHX heat exchanger to avoid issues with leaks using an inert and water/acid immiscible heat transfer fluid between the two sets of tube bundles. Boiler feed water can also be routed through the exchanger to remove the need for a pre-heater. In this way a double absorption plant can increase heat recovery from 70% to 90%, and higher still (95%) for a single absorption plant.

Other uses discussed for heat from acid plants included Aurubis and SmartSCOPE using waste heat from the Aurubis Hamburg smelter acid plant for district heating locally, while KVT Technology described using Oxysulf wet sulphuric acid technology to utilise sulphurous off-gases from a pulp and paper based bio-refinery, treat off-gases and generate additional heat and acid for the rest of the plant.

Catalysts and emissions

Catalysts are at the heart of any sulphuric acid plant, and Anders Madsen and Martin Alvarez of Topsoe delivered a comprehensive look at the relationship between catalyst size, shape, activity, pressure drop and mechanical strength. Jochen Willersinn of BASF presented his company's 04-116 Quattro quadrilobe acid catalyst, with increased vanadium content and potassium and caesium promoters as well as an increased pore size, designed to maximise SO_2 conversion and minimise SO_2 emissions from the plant. Johannes Hofer of P&P Industries meanwhile showcased their platinum promoted honeycomb catalyst VividOx, which can convert high SO_2 streams (up to 35%) in one reactor with over 95% conversion.

Acid plant design

Colin Bartlett presented Metso's paper on using oxygen enriched air to boost acid plant capacity in the Lurgi Recirculation process (LUREC). Although it has had operating references for more than a decade in China, Colin noted the conservatism of the industry in the uptake of new technology, remarking: "nobody wants to be first in this industry – everybody wants to be fifth."

Carolina Sanchez of Worley Chemetics went through the use of the CORE tubular reactor in flue gas desulphurisation – CORE-FGD – when there is a variable concentration of SO_2 in the gas stream. The system has recently been installed at a sour gas processing facility for Pertamina in Indonesia producing 192 million scf/d of sales gas. Using a regenerative scrubber to concentrate the SO_2 an acid plant capacity of 377 t/d has been achieved with a turndown capability of 20-100% of maximum. Acid production has actually been lower than expected due to lower sulphur content in the feed gas, though this illustrates the turndown capability of the process.

Mark Ferra of REXA described the importance of control systems actuators – actuators control when and how control valves are used and hence better control of the actuation leads to better control of the process and better results. REXA produce an electric motor with hydraulic transmission which costs more than a conventional pneumatic system but with much lower maintenance and precision that gives it a short payback period.

Daniel Ficklinger of Hugo Petersen examined the co-production of liquid SO_2 with sulphuric acid via condensation. The process can handle dynamic plant loads for variable production of acid vs SO_2, and is able to reuse process heat in the waste heat boiler and economiser.

Finally, on the literal nuts and bolts of plant design, NORAM took delegates through designs for ducting and expansion joints to accommodate combinations of thermal expansion and vertical movement.

Acid plant operation

Improvements in acid plant operation were shared by Steffen Haus of Metso, who presented some case studies of how digitisation of plant operations is increasing the efficiency of plant operation, and Combustion Solutions, who described a revamp of an acid plant using advanced burners and flow techniques to boost output from 2,200 t/d to 3,000 t/d. There was also operator input from Ayman Abd El Hafeiz of Abu Zaabal Fertilizer and Chemical in Egypt on improvements to their Plant no. 7 which had boosted the stability and reliability of operation, and Petrokimia Gresik, who had to make emergency repairs to a damaged stainless steel trough-type acid distributor during a recent shutdown. ■

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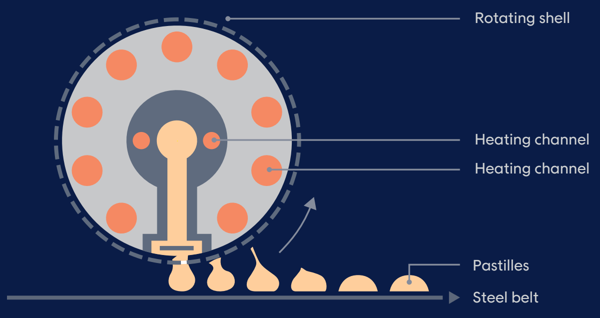

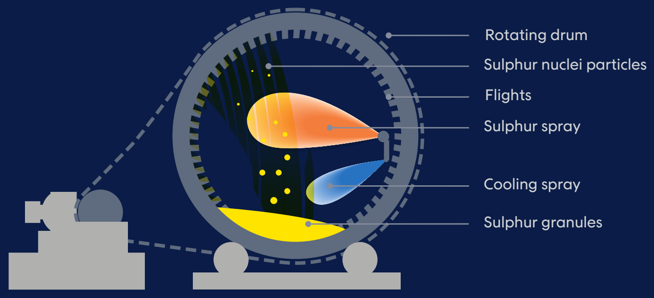

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The importance of cryogenic distillation technologies

As the oil and gas industry focus on new requirements for CO_2 recovery, cryogenic processes come under the spotlight. **Mahin Rameshni** and **Stephen Santo** of RATE USA discuss the importance of cryogenic processes in acid gas sweetening. Liquefied H_2S and CO_2 reinjection is proposed as a cost effective alternative to large sulphur plants.

Cryogenics is the production and behaviour of materials at very low temperatures – the branches of engineering that involve the study of very low temperatures (ultra-low temperature i.e. below 123 K), how to produce them, and how materials behave at those temperatures.

Acid gas streams, consisting primarily of hydrogen sulphide (H_2S) and carbon dioxide (CO_2), are commonly generated as a by-product of the gas sweetening process used to bring gases up to pipeline specifications for sales and transport. The conventional method for acid gas disposal is to have an acid gas sweetening unit to produce the sales gas and to use a Claus process to convert the H_2S to sulphur. However, new requirements for CO_2 recovery will add further costs to these projects.

In a typical sour gas field development with high H_2S content, the common practice is to produce a large quantity of sulphur. However, in order to meet pipeline sales gas quality, dehydration, hydrocarbon dew point control, nitrogen rejection, NGL and LPG recovery are required, for which cryogenic distillation is applied. New requirements call for additional CO_2 recovery from the stack, so-called flue gas decarbonisation which could refer to CO_2 liquefaction as one of the options which is also a cryogenic process and the most economical option.

The concept of CO_2 recovery and reinjection is expanded to both H_2S and CO_2 recovery and reinjection, which, ultimately would meet the emission requirements for both sulphur and carbon. The reinjection of H_2S and CO_2 can be optimised using an advanced cryogenic process.

It is well known that reinjection of H_2S and CO_2 in a gas phase requires large compressors to inject the gases deep underground. Safety aspects, H_2S leakage and large compressor stations are some of the cost factors to be considered. However, by using a cryogenic process, the H_2S and CO_2 can be converted into the liquid phase, allowing pumps to be used for reinjection, which brings a number of benefits:

- pumping a low pressure liquid is a lot less risky than compressing a high pressure gas;
- the advantage of having high concentration H_2S is that it can be more easily liquefied;
- putting the highest pressures underground under a wellhead is more reassuring from a safety manageability point of view.

RATE offers cryogenics technologies for the following applications:

- H_2S and CO_2 liquefied reinjection;
- CO_2 liquefaction and reinjection;
- hydrocarbon dew point control;
- NGL Recovery and LPG Product;
- cryogenic nitrogen rejection;
- cryogenic helium recovery;
- SO_2 liquefaction with or without a membrane.

The overall scheme of a sour gas field development is shown in Fig. 1. Cryogenic processes used in the design of a typical gas plant are highlighted.

Liquefied H_2S and CO_2 reinjection

Acid gas or liquefied acid gas reinjection involves three steps: separation and compression, dehydration and injection. The separation scheme is selected based on the feed composition, capacity, and energy consumption.

Cryogenic bulk removal of H_2S and CO_2 offers an economic advantage when the separated acid gases from the super sour gas are reinjected.

Acid gas or liquefied acid gas reinjection involves compressing the stream and injecting it into a suitable underground zone, similar to deep well disposal of produced water. Essentially, the sulphur compounds and CO_2 are permanently stored in the deep geological formation preventing their release to the atmosphere. Raw natural gas may contain significant impurities, with CO_2, H_2S, and N_2 being the most important.

"Sour gas" by definition is natural gas that contains H_2S. In order to meet sales gas contract specifications, sour gas must be treated for the removal of virtually all of the H_2S.

Some gas fields contain very high amounts of H_2S (more than 30 vol-%) or CO_2 (up to 70 vol-%) in natural or associated gases. For natural gas with high H_2S content, a chemical absorption process with an amine may be used. Typically, the amine absorption method captures most of the CO_2 in addition to the H_2S. The resulting $CO_2 + H_2S$ (acid gas) must then be processed to eliminate the H_2S. The least cost method to eliminate H_2S is to

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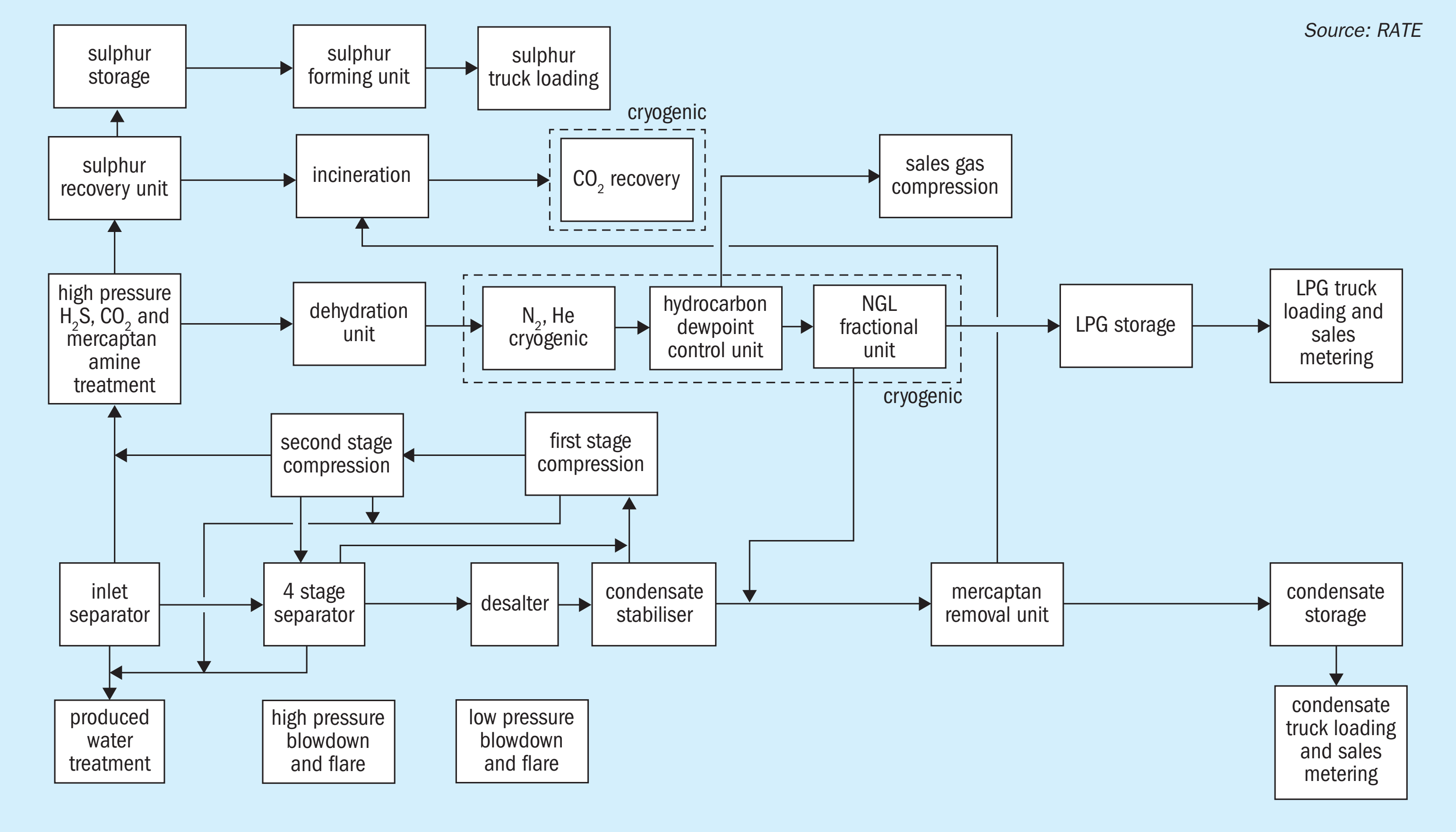
Fig. 1: **Overall scheme of a sour gas field development**



Source: RATE

flare the acid gas stream, burning the H_2S to SO_2 and releasing the CO_2 to the atmosphere, along with the SO_2. However, over recent decades, concerns for the environmental effects of sulphur emissions have eliminated flaring as an option for all but the very smallest facilities. Another option is to process the acid gas in a sulphur recovery unit such as a Claus plant, which produces sulphur as a saleable byproduct, but releases the CO_2 as before.

Acid gas or liquefied H_2S and CO_2 stream injection is an important step towards large-scale capture and geological storage of CO_2 emissions. It provides an alternative solution to conventional sulphur recovery and tail gas treating units and could serve as a foundation for mitigating CO_2 emissions through geological storage

Present energy prices, which are expected to remain substantially higher than before the oil crisis, make the production of even very acidic natural gases attractive. There is therefore an incentive to develop new processes, specifically for this purpose.

This purification can be advantageously carried out by a cryogenic process. However, the thermodynamic behaviour of natural gases containing H_2S and CO_2, becomes very complicated in the low temperature zone, mainly because CO_2 may crystallise and H_2S may cause liquid immiscibility.

Cryogenic distillation processes offer many advantages when the separated acid gases need to be re-injected to limit undesired sulphur production or to minimise greenhouse gas emissions to the atmosphere. They are very selective towards light hydrocarbons, and the separated acid gases (H_2S and/or CO_2) are recovered in the liquid state under pressure. Producing the acid gases as a high pressure liquid reduces the pumping duty, saving on expensive and energy consuming compression requirements.

RATE offers a variety of schemes to meet project requirements, such as using a membrane in combination with cryogenics liquefaction or the combination of a membrane with selective solvent amine units to remove the bulk of H_2S and CO_2 and to polish the gas to meet pipeline specifications.

The scheme selected for the acid gas removal section will depend on the acid gas composition and its impurities. If the acid gas contains mercaptans, hybrid solvents are typically used, otherwise chemical solvents are used followed by a polishing unit using adsorbents, mole sieves, or even physical solvents. For energy savings, the combination of a membrane and an amine unit with a selective solvent is usually selected.

In order to use a liquefied acid stream the most economical scheme is to use the combination of a two-stage membrane with the acid gas liquefaction scheme, where the liquefied H_2S and CO_2 stream is pumped from the surface.

Two-stage membranes are specifically designed to separate H_2S and CO_2 from the natural gas. Natural gas is used as the product and H_2S and CO_2 are sent to the liquefaction process to convert them into the liquid phase. If the sour gas contains heavier hydrocarbons, above C_4, some of the heavier hydrocarbons may dissolve in the stream containing H_2S and CO_2, but in the majority of cases sour gas fields do not have heavy hydrocarbons.

There are two options to treat the recovered acid gas: liquefied acid gas reinjection or conventional sulphur recovery and tail gas treating technologies. The liquefied H_2S and CO_2 stream would be ready for reinjection after necessary steps like dehydration.

The acid gas removal technology selection is based on the selection for reinjection or to produce sulphur.

The sales gas product is separated and dehydrated and may require hydrocarbon dew point and nitrogen rejection cryogenic processes before it is routed to the pipeline.

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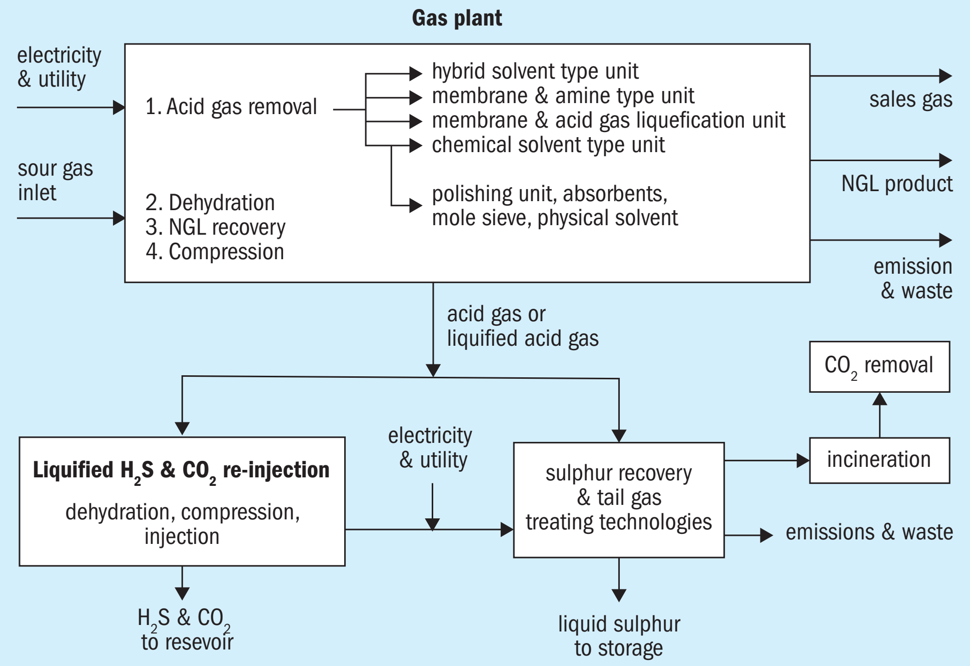
Fig. 2: **Typical gas plant with acid gas / liquified acid gas reinjection**



Source: RATE

Fig. 2 represents a typical gas plant with the option of acid gas or liquefied acid gas re-injection, where H_2S and CO_2 are both reinjected, versus a conventional sulphur recovery unit to produce sulphur and flue gas decarbonisation to remove the CO_2 e.g., by CO_2 liquefaction which is the most cost effective option.

CO_2 liquefaction reinjection

CO_2 recovery to reduce greenhouse gases from the atmosphere, is one of the hot topics which the oil and gas industry is focusing on and that includes the sulphur plants as well. A number of separation technologies could be employed with post-combustion capture. These include: (a) adsorption; (b) physical absorption; (c) chemical absorption; (d) cryogenics separation, (e) membranes, and (f) RATE technology CO_2 liquefaction. On the other hand, pre-combustion technologies include: (a) adsorption; (b) physical absorption; (c) chemical absorption; (d) cryogenics separation, (e) membranes, and (f) RATE combination of a membrane and CO_2 liquefaction or selective amine unit.

RATE offers various CO_2 removal options depending on the application:

- CO_2 liquefaction process with pre and post combustion
- Flue gas decarburisation, including Incineration stack
- CO_2 liquefaction process in combination with a membrane, for natural gas
- Selexol process with or without CO_2 liquefaction upstream of the SRU
- Selexol with a mole sieve upstream of the SRU
- Rotating packed bed system
- Regenerable and non-regenerable adsorbents
- Adsorbents and membrane standalone or with an amine unit
- Generic amine / formulated solvent, chemical, physical / hybrid solvent
- RATE technology "Deep CO_2 removal" bypass part of the acid gas containing high CO_2

The recovered CO_2 is then stored or reinjected as described above.

Fig. 3 represents the CO_2 liquefaction process.

Hydrocarbon dew point control

The gas from the dehydration unit is treated in the hydrocarbon dew point process. Dew point control plants also produce NGL and LPG, but their main purpose is to eliminate hydrocarbon condensation in pipelines and downstream process units.

The technology selection for this unit depends on the NGL feed composition. The project requires 90% propane recovery. The hydrocarbon dew point process consists of a Joule Thomson (JT) valve with mechanical refrigerator or turbo expander. The option selected is based on 90% propane recovery in the NGL section.

The hydrocarbon dew point is the temperature, at a defined pressure, at which hydrocarbon liquids begin to form. The determination of the hydrocarbon dew point (HCDP) for natural gas has become a critical issue for the natural gas industry because of the rapid expansion of interconnecting pipelines and the rise of non-traditional sources of natural gas. Hydrocarbon liquids in the gas stream can cause hydrate formation, increase compression costs, cause issues with pressure regulator freezing, and lead to damage to end-user equipment such as gas turbines. To protect against this risk, custody transfer agreements are increasingly specifying limits for the HCDP, which, in turn, requires a reliable method of reporting the HCDP at the custody transfer location.

The JT assembly provides hydrocarbon dew point control and increased recovery of natural gas liquids (NGL). The JT plant consists of a gas-to-gas heat exchanger with hot gas bypass, liquid-to-gas heat exchanger, JT valve, cold separator, methanol injection system and control system, all mounted on a single skid. Following gas/liquid separation and gas dehydration, high-pressure gas enters the assembly through the gas/gas exchanger and chiller for pre-cooling. Methanol is injected to prevent formation of hydrates, and the raw natural gas passes through a JT valve. The resulting pressure drop causes expansion of the gas and a significant temperature reduction due to the Joule-Thompson effect. The cooled gas is routed to the cold separator to remove the condensed NGL. The outlet gas from the cold separator is routed through the gas/gas exchanger for inlet cooling. The NGL from the cold separator is routed through the inlet NGL/gas exchanger and then to a separate optional pressurised NGL fractionation unit.

The turbo expander assembly provides hydrocarbon dew point control and increased recovery of natural gas liquids (NGL). Refrigerated gas plants recover a large fraction of propane and heavier gases.

JT plants are simpler in design and use high-pressure gas energy to liquefy heavier components by throttling. The Joule-Thomson effect is a physical principle that changes the gas entropy through pressure reduction and produces chilling. Turbo expanders recover a large fraction of ethane and heavier gases.

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Recovery rate estimation

Although the amount of hydrocarbon condensate available for recovery may be known, it is important to realise that no process is capable of recovering 100% of this amount. Depending upon the NGL recovery process chosen and the operating parameters set, the total recovery and recovery amount for each component may change dramatically. Additionally, the same equipment processing a stream containing a higher concentration of NGLs will have a higher recovery rate than when processing a leaner stream.

As a rule of thumb, recovery rates for condensate recovery options are roughly:

Joule-Thomson (JT) plant:
- ethane recovery: <20%
- propane recovery: 60%
- butane and heavier recovery: 80%

Mechanical refrigeration:
- ethane recovery: 40%
- propane recovery: 80%
- butane and heavier: 90%

Cryogenic expansion:
- ethane recovery: 90% minimum
- propane recovery: 95% minimum
- butane and heavier: 99%

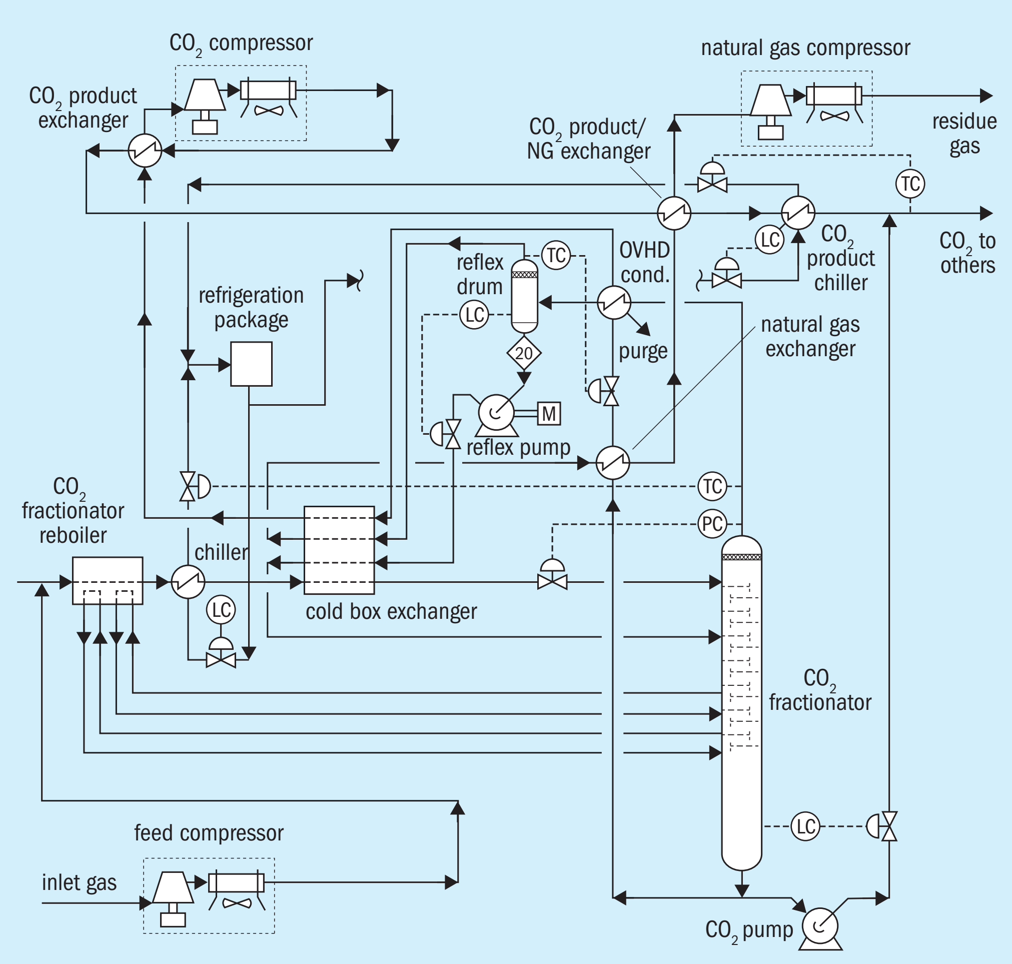
JT valves with mechanical refrigeration are selected to achieve near 90% propane only and there is no need for ethane recovery to reduce the capital investment. In addition, due to high recovery of propane, mercaptan treatment is provided on the LPG stream.

NGL recovery and LPG product

In order to understand NGL recovery technologies, it is important to first understand their role in the processing of natural gas. Natural gas may contain ethane, propane, methane and other valuable heavier hydrocarbons. Depending upon market conditions, the recovery of these condensable hydrocarbons, known as NGLs or hydrocarbon condensates may be quite lucrative. Due to the capital and operating expenses typically required to set up and run such a project, careful planning and economic valuation is required.

Natural gas processing using JT with mechanical refrigeration enables the collection of condensates in the absence of high pressure gas sources. The chiller in a mechanical refrigeration unit cools associated gas below -20°F (-29°C) which increases the pressure range over which condensates can condense into liquids. Mechanical refrigeration is flexible in the pre-treatment required, but may leave a significant percentage of condensates unremoved depending on gas composition.

Fig. 3: **CO_2 liquefaction**



Source: RATE

The main advantages are:
- Higher recovery rates than with standalone JT plants;
- No pressure loss is incurred on the gas stream.
  - ❍ Potentially allows unit to be installed within existing process with minimal difficulty.
- Compression costs are lower than with JT plants
- Much less expensive than cryogenic separation processes.
- May be modular, allowing for rapid relocation.
- A single unit may be able to handle a large range of incoming gas flow rates.
- Condensate recovery may be 'tuned' by adjusting the operating pressure.
  - ❍ Higher pressures will cause increased recovery of propane and ethane.

In the NGL unit, the propane will be recovered and the product LPG flows to the storage facility.

With high propane recovery and the selection of hydrocarbon dew point the mercaptan removal is only provided on the LPG stream.

Cryogenic nitrogen rejection

When extracted, natural gas is a mixture of gases, with hydrocarbons being the main component. However, raw natural gas also frequently contains the inert gas nitrogen. Nitrogen lowers the heating value of natural gas and increases transport volumes. The challenge lies in reducing this nitrogen content to typically 3 to 4% for pipeline specifications or even 1% for storage as liquefied natural gas (LNG).

Helium is a rare gas and highly valued in the market, making its recovery and liquefaction from natural gas an attractive option even in small amounts. So, if helium is also present in the natural gas stream, nitrogen rejection is typically combined with the recovery of helium. High

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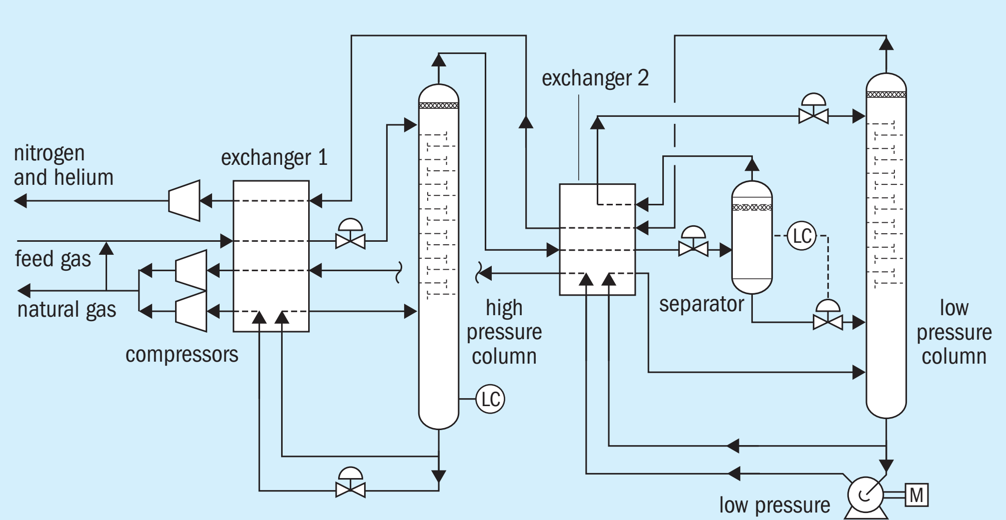
Fig. 4: **Cryogenic nitrogen rejection**



Source: RATE

Note: Each compressor is considered as a package that includes interstage cooling

purity helium is obtained by combining cryogenic and pressure swing adsorption process steps.

There are many gas reservoirs worldwide that contain high levels of 'naturally' occurring nitrogen. The nitrogen content in the produced gas of these reservoirs usually remains constant over the producing life of the reservoir. The design of the nitrogen rejection unit (NRU) can focus on an optimum design at a fixed feed composition. Usually, nitrogen is not injected into these reserves to enhance recovery, so the rejected nitrogen has little or no value as a product stream. For this reason, the product nitrogen pressure at the outlet of the process is not important. On the other hand, the hydrocarbon recovery from the vented nitrogen is very important: a typical value for hydrocarbon recovery is 98%.

Cryogenic nitrogen removal is designed based on the nitrogen content. For inlet gas containing less than 20% nitrogen a single distillation column is used. For inlet gas containing more than 20% nitrogen, a double column or 2 column configuration is used. For inlet gas containing above 50% nitrogen, 3 columns are used. The energy consumption and the recovery depends on the inlet gas compositions, and the required recovery.

Fig. 4 represents the cryogenic nitrogen rejection process.

Cryogenic helium recovery

The vent gas from cryogenic compressor contains N_2, helium and H_2 and is sent to the second stage compressor before entering the helium column via the box exchanger. The tower includes a reboiler and condenser. The H_2 is minimised before entering this system. The tower overhead flows to the PSA helium removal unit through the box exchanger. The liquid nitrogen is recovered from the bottom of the column through box changer. The helium is separated and may contain some hydrogen. The PSA vent is separated.

Fig. 5 represents the cryogenic helium recovery for a gas plant.

SO_2 liquefaction

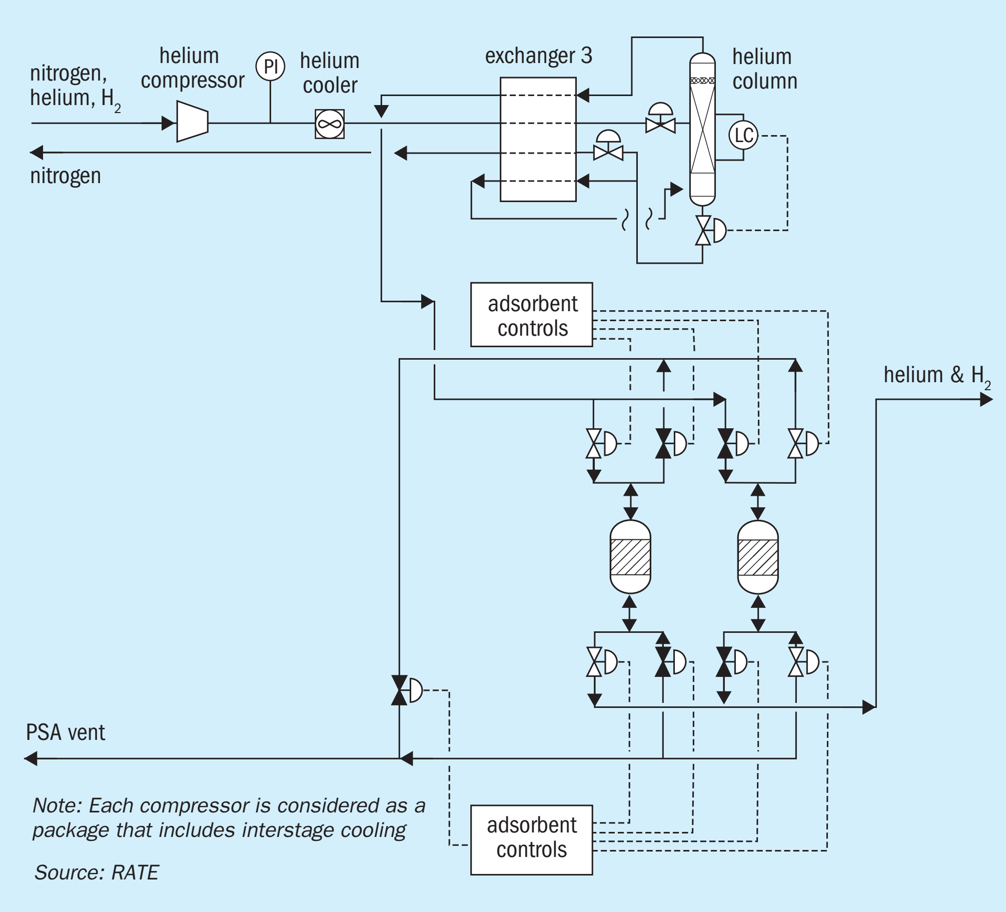
Mining facilities such as smelters, e.g. in copper mining, produce sulphuric acid from the SO_2 streams from furnaces. The amount of SO_2 generated in these processes can vary and it may not be possible to control the amount of generated SO_2. In cases where the existing sulphuric acid is operating at maximum capacity and is not capable of receiving more SO_2 gases, one option is to use SO_2 liquefaction to store the additional SO_2 in a dedicated storage tank. This solution prevents the SO_2 from being emitted to the atmosphere and does not require an additional sulphuric acid unit.

Sulphur dioxide can be liquefied under moderate pressures at room temperatures; the liquid freezes at −73°C (−99.4°F) and boils at −10°C (14°F) under atmospheric pressure.

Liquid SO_2 can be produced from gas containing SO_2 concentrations in the range from 1% to 100% using different processes:

- compression and condensation – for high SO_2 concentration;

Fig. 5: **Cryogenic helium recovery in a gas plant**



Note: Each compressor is considered as a package that includes interstage cooling

Source: RATE

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- partial condensation – 7 to 14% SO_2 Concentration;
- absorption and acidification – 1 to 2% SO_2 concentration;
- sulphur trioxide and sulphur – other application;
- SO_2 liquefaction with membrane.

In this article two options are evaluated. The total feed was assumed as 10,000 t/d with 18% SO_2.

SO_2 liquefaction only

When the concentration of SO_2 in the gas is low (typically 7-14%), it becomes impractical to attempt to fully condense all the SO_2 contained in the gas. Extremely high pressures are required in order to use cooling water to condense SO_2 from the gas. The alternative to full condensation is partial condensation of the SO_2 using refrigeration only. Refrigeration systems can achieve temperatures as low as -55°C (-67°F). Typically, only 50% of the SO_2 can be condensed from the gas. The tail gas from the refrigeration process is used to pre-cool the incoming gas prior to being directed to another process for further treatment, e.g. in a sulphuric acid plant.

SO_2 liquefaction with membrane technology

In this process, the temperature makes a big difference to the SO_2 recovery. At 60°F (16°C) the SO_2 recovery is 50% and at 40°F the SO_2 recovery is 66%. Without membrane technology the SO_2 recovery at 60°F is zero and the SO_2 recovery at 40°F (4°C) is 25%.

Membrane technology increases the SO_2 recovery significantly. At SO_2 concentrations below 30%, SO_2 liquefaction only is more expensive with less SO_2 recovery, while SO_2 liquefaction with membrane technology has a much higher recovery of SO_2 and lower electricity consumption.

Conclusions

As discussed above, cryogenic processes have become more essential due to new challenges in the feedstock of sour gas field developments as well as new environmental regulations.

According to RATE's evaluation, for natural gas with a high content of H_2S, the configuration of a membrane followed by acid gas liquefaction will result in the lowest capital and operating costs and will provide much safer operation by using pumps. In addition, it provides a significant reduction of the utility consumptions compared to other acid gas removal options.

Reinjection of H_2S and CO_2 in the liquid phase provides significant safety features and reduces safety concerns in addition it reduces the capital and the operating costs and reduces mega size compressors station and the electricity consumption. Liquefied H_2S and CO_2 reinjection provides an alternative to large sulphur plants.

Other cryogenic schemes that are important in CO_2 recovery such as CO_2 liquefaction are also discussed. Some other cryogenic processes and parameters such as hydrocarbon dew point and nitrogen rejection have an important role to meet the new sales gas specifications. ■

References

1. Rameshni, M.: "CO_2 recovery options in sulphur plants", Sulphur 404 (Jan-Feb 2023)
2. Rameshni, M.: "Sulphur plant revamps to meet future challenges", Sulphur 409 (Nov-Dec 2023)

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Advanced feed gas control by detecting BTEX in SRU feed gas

The development and implementation of modern process instruments and control systems in sulphur recovery units has increased significantly over the last decade. In this article, the impact of BTEX on sulphur plant operations and how the BTEX concentrations can be measured are discussed.

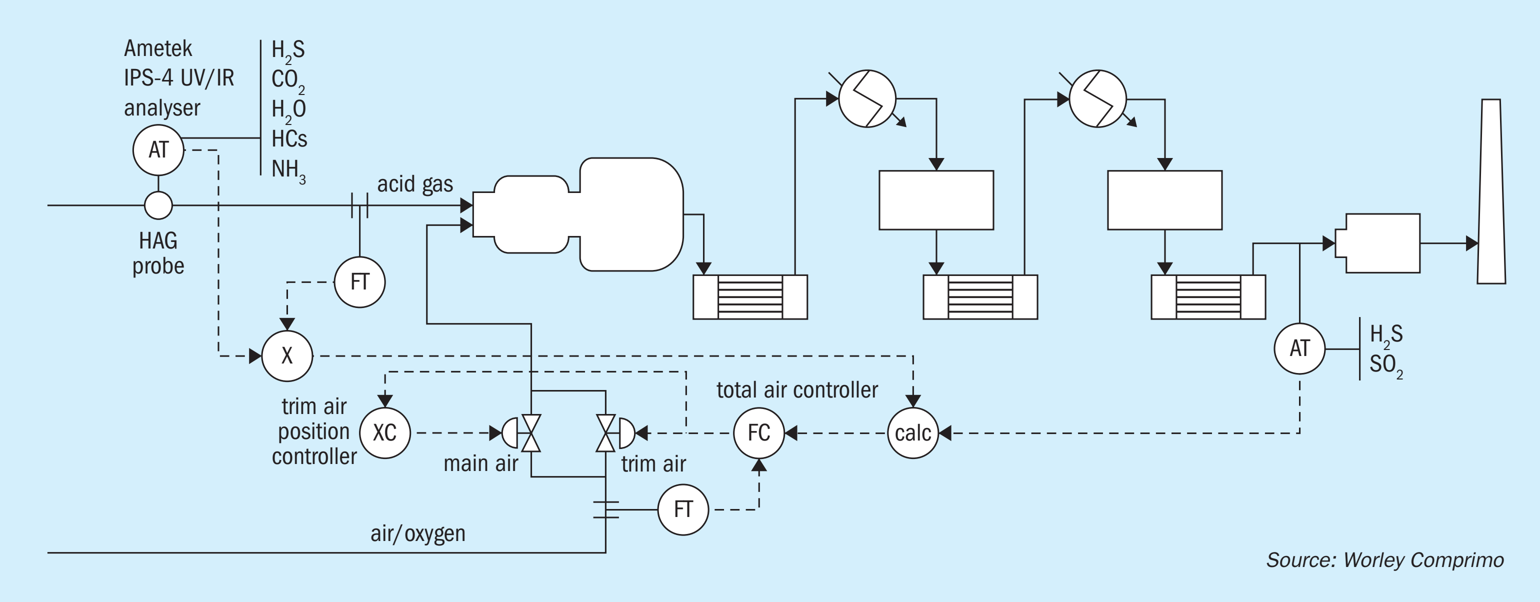
Michael Gaura, Jochen Geiger, Harry Burton (AMETEK Process Instruments)

In some hydrocarbon processing plants and refineries, benzene, toluene, ethylbenzene and xylene (BTEX), can be present in the feed gas to the Claus thermal reactor. Unlike the lighter hydrocarbons, the complete destruction of BTEX requires the reactor to operate at over 1,100°C. If BTEX destruction is not complete, soot is likely to form on the catalytic beds. For refineries this is not usually a concern as most modified Claus process units are designed to handle sour water stripper gas (SWS), which contains a percentage of ammonia (NH_3). In such cases the reaction furnace temperature is kept above 1,200°C, but for natural gas processing plants it is a real concern, as the normal reactor operating temperature is below 1,000°C, making co-firing mandatory.

Several recent papers and presentations regarding operational improvements using advanced process control strategies for modified Claus plant operations have been published. The basis of this approach is the measurement of the most critical components – hydrogen sulphide (H_2S), total hydrocarbons (THC), carbon dioxide (CO_2), ammonia (NH_3), if present and water (H_2O) "not standard" – in the feed gas to the thermal reactor, to better manage the combustion air:oxygen use. Optimising this acid gas (feed gas) to air flow ratio is the key target. In addition to process efficiency gains, through higher recovery efficiency and SRU throughput, and cost savings through the use of less air or oxygen, better combustion management can also reduce CO_2 emissions, which are increasingly being measured, reported and regulated. With tighter control of the entire modified Claus unit, upset conditions can also be mitigated resulting in reduced emission violations and greater sulphur recovery efficiency.

Another area for improvement in sulphur recovery operations is the better

Fig. 1: **Worley Comprimo 2ACT Solution process schematic**



Source: Worley Comprimo

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management of co-firing. When incoming acid gas is lean in terms of hydrocarbon content, the introduction of additional "fuel" to the thermal reactor (co-firing) is required. Ideal co-firing properly manages the introduction and use of natural gas in order to maintain a thermal reactor temperature that is high enough to destroy any BTEX present. But the use of natural gas is not desired, as it represents a reduction in sellable gas, i.e. a financial loss for the gas producers. Improper co-firing can also result in inefficient combustion, with increased CO_2 generation as a negative outcome.

Looking for answers

With a solid installed base of Claus feed gas analyser systems built up over multiple decades, a lot of historical data is available. This data includes operational experiences and learnings. The first instruments installed were aimed at looking into H_2S and NH_3, and really only served to provide insights into what was entering the SRU. Later, when more advanced analysers, capable of incorporating multiple measurement technologies became available, measurements for THC, CO_2 and H_2O were added. The additional measurement of THC has been extremely valuable, as plant operators are able to adjust the amount of air or oxygen they are delivering when the THC concentrations are varying. When present, THC "steals" oxygen from the H_2S to SO_2 conversion process. And when the THC suddenly goes away, there is surplus O_2 present, which leads to excess SO_2 production in the modified Claus plant.

With near complete understanding of the concentrations of the gas compounds entering the SRU, plant operations can operate more efficiently, more safely and with fewer emission incidents. For those that are not completely certain how to incorporate this analytical data into their control systems and recognise plant improvements, a company like Worley Comprimo with its Analyser Air Control Technology, "2ACT™ solution (see Fig. 1), can assist. Some plants are already benefitting from the 2ACT solution and there is a growing interest in it from design engineers and plant operation managers.

> **"With near complete understanding of the concentrations of the gas compounds entering the SRU, plant operations can operate more efficiently, more safely and with fewer emission incidents."**

Fig. 2: **An IPS 4 and a HAG (Heated Acid Gas) probe**

Source: AMETEK

It is important to acknowledge that because the measured components (specifically H_2S) are highly dangerous to humans, an area of concern when performing measurement of this feed gas is the safety of the maintenance team.

To minimise some of the risks associated with both performing this measurement and maintaining the analyser without compromising the reliability of the measurement, it is important to use an appropriate sample probe. The probe should be heated, have a means of filtering out liquids and particulates, and be designed with multiple shut off valves for both the sample inlet and outlet paths. One such probe is shown in Fig. 2 – the AMETEK Heated Acid Gas or HAG probe.

The analyser operation and maintenance should also be easy to understand and perform. The use of analysers that include several consumable items that need to be frequently replaced should be avoided. An analyser should be selected that can be serviced by the local maintenance team, so there is no need to wait for an expert to come to the plant.

However, because of the location of the measurement, individuals assigned to work on this analyser system should be experienced and clearly understand that the sampled gas stream will almost always be dangerous to personnel safety. The impact of "human error" should never be ignored and detailed work instructions should be present and followed.

The benefit of feed gas measurement

As experience with performing feed gas measurement has increased, additional points of process improvement are being evaluated, for example, the potential measurement of BTEX, but can this measurement be achieved?

From an analytical standpoint, we need to understand that the process analyser used for this kind of measurement is a combined ultraviolet / infrared instrument. Both spectral regions are required to perform this combination of measurements. For example, most of the hydrocarbons and water (H_2O) are fully transparent (not detectable) in the ultraviolet (UV) regime. On the other hand, the component of main interest, hydrogen sulphide, is very challenging to make in the infrared (IR) absorbance spectra. The simple reason for this effect is that water IR absorbance is present at similar wavelengths as H_2S. This poses a risk to the H_2S IR absorbance measurement, as the absorbance would not be true to H_2S alone. This effect is called interference / cross-sensitivity.

BTEX aromatic components exhibit both electronic and vibrational absorbances when adequately stimulated, meaning they have a detectable absorbance in both the UV-Vis and IR wavelength regimes. The AMETEK IPS-4 includes both UV and IR optical benches, making it a unique analytical tool for this measurement application.

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The IR bench uses several narrow bandpass filters with pre-selected central wavelengths to isolate the absorbances from IR species of interest. Careful selection of bandpass filters aids in the reduction of interference, as it blocks the transmission of light from wavelengths not allowed to pass through the filter. The efficacy of the IR bench isn't without its limitations. For example, total BTEX measurement in the IR is not suitable due to the overlapping spectra of components, as illustrated in Fig. 3. These aromatic compounds have similar carbon ring bond behaviour, meaning their absorbance spectra is likely to superimpose when given sufficient concentrations.

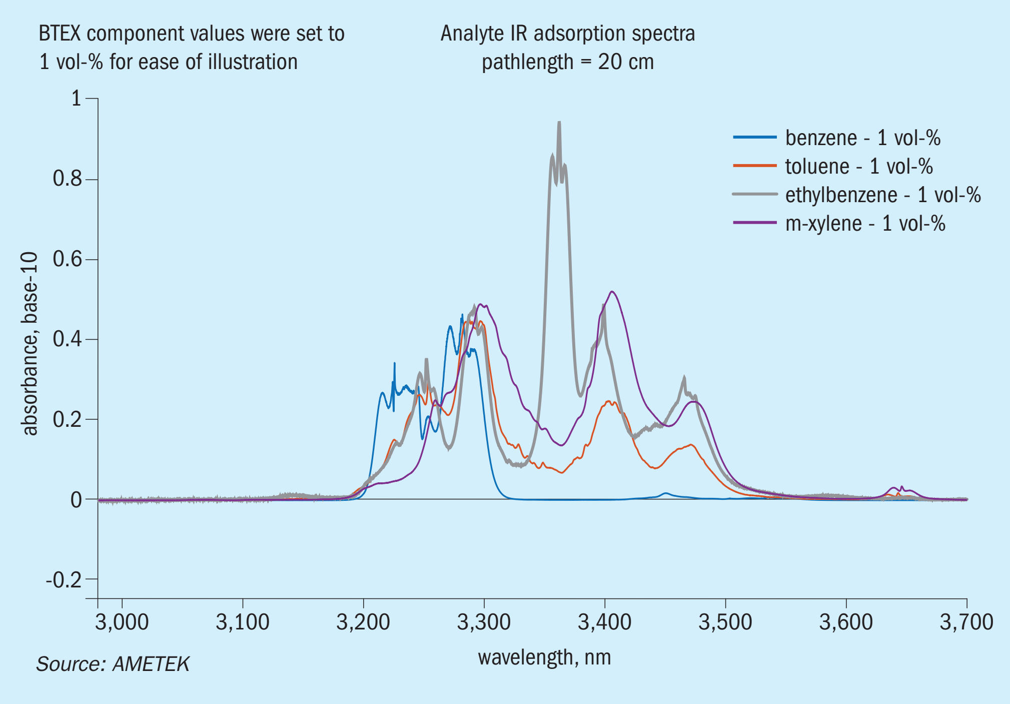
In contrast, the xenon flashlamp and diode array structure of the IPS-4's UV bench provides selective and speciation capabilities that the IR bench lacks. This bench benefits heavily from the use of a diode array, which can collect the absorbance from multiple wavelengths. Collecting multiple wavelengths enables the use of more complex regression techniques for improved speciation, such as principal component analysis (PCA). Additionally, BTEX components in the UV regime exhibit enough distinguishing absorbance characteristics that further improves the efficacy of a PCA approach. For these reasons, a speciated BTEX measurement is most likely to see success when analysis is performed within the IPS-4 UV-optical bench. Fig. 4 showcases an example of BTEX absorbance cross-section spectra in the UV regime.

With the IPS-4 UV bench as the starting point for BTEX measurement, the next focus turns to what reasonable concentration limits can be made across all components. There are multiple factors at play here that can affect the instrument's capacity for a successful measurement:

- What is the end-user's typical concentration range for each BTEX component?
- At what process pressures and temperatures do we expect the sample gas to be supplied at?
- If H_2S is present, what can we anticipate as the typical and maximum concentration levels?
- Are other contaminants present in the supplied sample (such as other sulphur-based species, amines , moisture, etc.)?

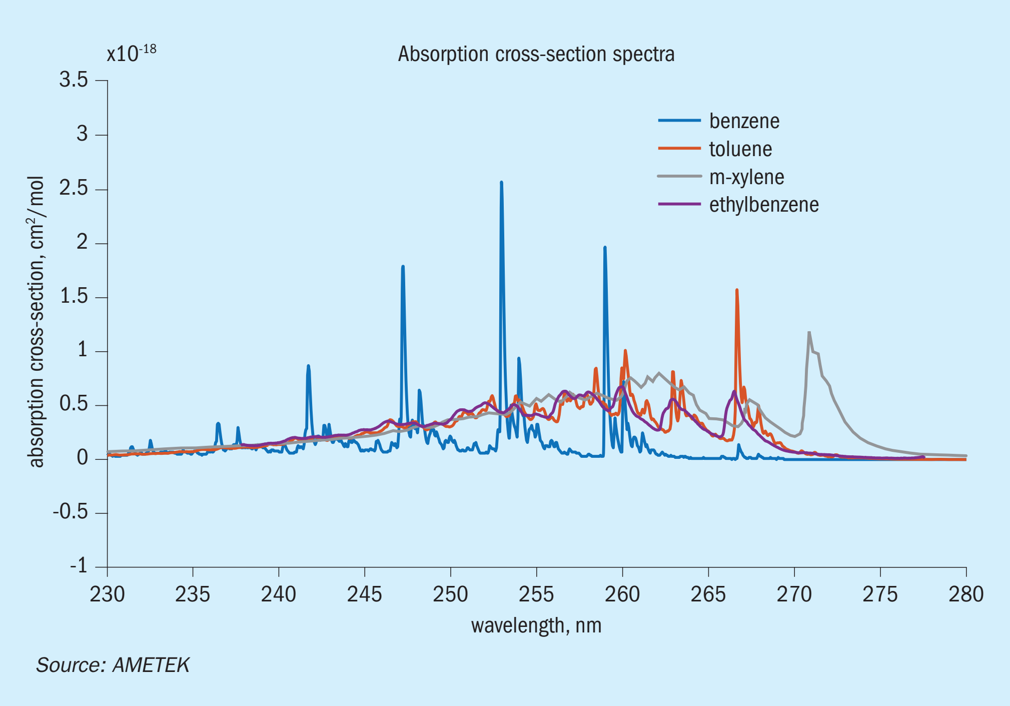
These are only a handful of questions specific to the application, but acquiring information for each subject is important.

Fig. 3: **Benzene, toluene, ethylbenzene, and m-xylene gas mid-IR absorbance spectra**



Source: AMETEK

Fig. 4: **BTEX UV absorption cross-section spectra**



Source: AMETEK

All BTEX components exhibit UV absorbances within the 230 to 275 nm band. But there is an issue of potential sulphur absorbance interference (the latter being especially important with the expected high percentage levels of H_2S). Benzene has the fewest number of carbon bonds and so exhibits the least amount of absorbance relative to toluene, ethylbenzene, and xylene. Xylene, in particular, is unique because of its various isomers, (ortho-, meta- and para-xylene), which can also influence its absorbance characteristics. Traditionally, in feed gas, these components are not seen in concentrations of more than 2,500 ppmv.

These factors play a role in the minimum detectable concentration value that the IPS-4 can measure. As this BTEX will be in the gas phase, pressure and temperature will also influence the absorbance results due to pressure broadening effects and temperature related effects on the electron transition states of each BTEX component. A major

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limiting factor in BTEX measurement, however, will likely be H_2S. This sulphur component exhibits a strong absorbance at wavelengths of <230 nm, but this absorbance can extend several wavelengths further depending on the pathlength chosen to compensate for BTEX measurement.

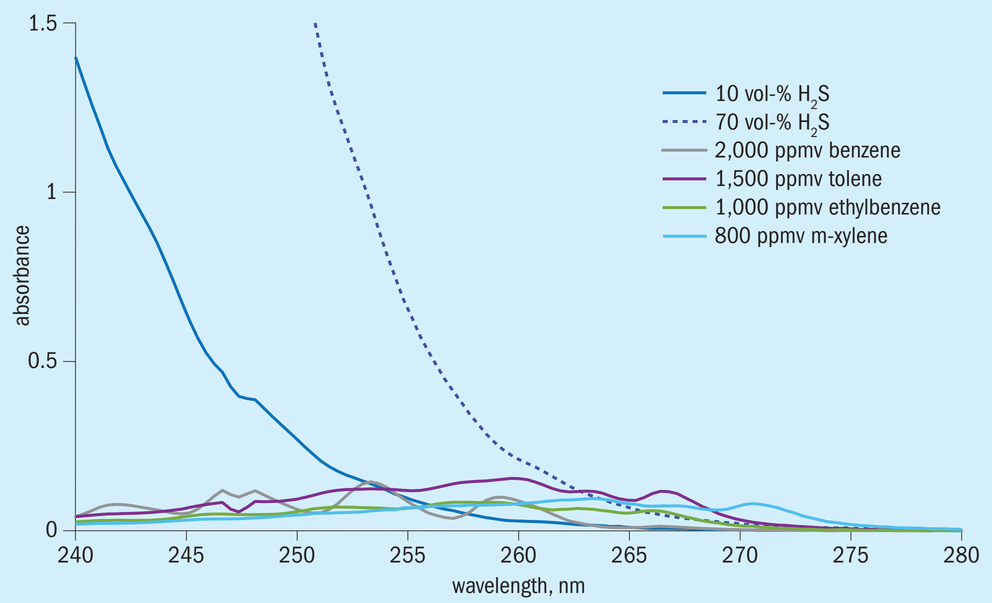
The significance of H_2S on the efficacy of a BTEX measurement cannot be understated, as it will be the primary limiter on the minimum concentrations needed for each BTEX component. As an example, an IPS-4 analyser shipped to a gas processing unit was intended to measure BTEX in the presence of H_2S. During calibration, the following concentrations of each BTEX component was used:

- benzene: 2,000 ppmv;
- toluene: 1,500 ppmv;
- ethylbenzene: 1,000 ppmv;
- m-xylene: 800 ppmv.

Because this sample process was also in the presence of H_2S, typically 10 vol-%, but with a max. of 70 vol-%, the total wavelength band that is usable for BTEX calibration is significantly reduced. This is primarily due to H_2S absorbance saturation of the BTEX absorbances, creating what amounts to statistical noise. Fig. 5 illustrates this behaviour for reference. Given this behaviour, there's a give-and-take relationship between minimum BTEX concentrations, acceptable H_2S concentration levels, and the pathlength used in maximising BTEX absorbance.

Through analysis and testing, AMETEK found that adding a total BTEX measurement in addition to the measurement of the "classic" feed gas components is possible. Similar to the measurement of total hydrocarbons (THC) there is no differentiation between benzene, toluene, ethylbenzene, and xylene. The output is presenting the total BTEX.

Fig. 5: **Effect of H_2S on BTEX measurement**



Source: AMETEK

How to use the information

It is well understood, and previously mentioned, that the presence of BTEX can lead to major issues with the Claus catalysts. But what can be done? Permanent co-firing under the premise "let's be on the safe side" will lead to higher CO_2 emissions. Permanent co-firing is also a direct loss of money as the gas which is co-fired cannot be sold. So, the best case would be that BTEX would be prevented from entering the Claus thermal reactor. And in some cases, BTEX removal systems are used. But can these systems consistently remove all of the BTEX? AMETEK experiences indicate that they do not. So, preventing BTEX from ever entering the SRU is not realistic, making it a good idea to measure for it and know when it is entering and at what concentrations. BTEX will not be permanently present in the feed gas and will vary in concentration when it enters the SRU.

Because the amount of co-firing gas used depends on how much BTEX is present, considerations similar to those made for the presence of THCs are required and must be made quickly. Any BTEX concentration increase should immediately increase the amount of co-firing gas to ensure it is properly thermally destroyed while any BTEX concentration decrease should result in a reduction in co-firing gas. After the BTEX goes away, the continued introduction of co-firing gas will result in wasted sellable gas and increased CO_2 production, both negative outcomes.

Although speciation of the BTEX components is analytically possible with process gas chromatography (PGC) technology, the GC's cycle time is too long to properly report changes in feed gas BTEX levels, thus significantly reducing any real improvements of co-firing gas management in the thermal reactor. However, these speciated measurements can be beneficial to a process specialist that is trying to better understand the root cause of the presence and varying concentrations of BTEX at the thermal reactor. Something to keep in mind.

Summary and conclusion

The initial investment in a feed gas measurement analyser and burner control system is not negligible and the application challenges are high with regards to measurement reliability and safety aspects (the SRU has the most toxic gas mixtures of the entire refinery). Successful examples exist of users that are benefitting from these analyser + control system configurations. But these installations work because of the cooperation of different functional teams. In order to achieve the goals of improving and optimising the overall unit performance, different technical disciplines have to work together, starting at the design phase of the processing unit and continuing through use of the analytical measurements during operation and proper predictive and reactive maintenance of the analytical devices. Choosing a "basic" instrument may result in not achieving the best possible process performance.

By adding BTEX measurement to the feed gas control system, plant operators can better adjust and control co-firing. This will lead to less natural gas use, optimal oxygen introduction, lower CO_2 emissions, and longer catalyst life. Depending on current operational measurements and practices, significant money savings can be achieved. ■

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Sulphur degassing systems for large scale sulphur recovery units

Marcus Weber of Fluor discusses degassing units for large scale sulphur recovery units, evaluating the pros and cons of various available commercial technologies with the emphasis on mega size sulphur recovery units and focussing on how technology can lower degassing capex via economy of scale for new facilities or existing facilities undergoing expansion.

Why is sulphur degassing necessary?

Sulphur produced in Claus sulphur recovery units (SRUs) typically contains dissolved hydrogen sulphide (H_2S) and polysulphides (H_2S_X) in the rundown sulphur in the range of 200 to 600 ppm. This hydrogen sulphide when released from the liquid sulphur results in a concentration that can be toxic and if allowed to concentrate in closed spaces can increase to levels above the lower explosive limit and then also presents a flammability/explosive hazard.

Most regulatory bodies, transportation companies and end users require sulphur product specifications with 10 ppm or less H_2S. Due to the toxicity and environmental hazards associated with H_2S, sulphur is typically degassed within the SRU. If sulphur is not degassed within the SRU, it typically presents an H_2S emissions concentration issue that requires additional sweep gas or other methods to control H_2S emissions as it is transferred to downstream storage.

Table 1: **H_2S concentrations and associated risks**

Risk/symptom	ppm	Volume %
Odour threshold to humans	0.00047	
Maximum occupational allowable concentration /eye irritation	10	0.001
Respiratory tract irritation after 1 hour exposure	50-100	0.005 - 0.01
Coughing, eye irritation, loss of sense of smell after 2-15 minutes	100	0.010
Loss of consciousness and possibly death in 30-60 minutes	500 - 700	0.050 – 0.070
Rapid unconsciousness, cessation of respiration and death	>700 - 1000	>0.070
Lower explosive limit (LEL)	43,000	4.3
Upper explosive limit (UEL)	450,000	45%

Source: Fluor

While not directly impacting sulphur degassing, most new SRU units are required to meet World Bank Standards of 150 mg/Nm^3 SO_2 emissions in the incinerator flue gas in addition to 99.99+% sulphur recovery efficiency (SRE). Sweep gas requirements for liquid sulphur storage pits/vessels/tankage can be rather large, further increasing capex/opex due to sweep gas recycle requirements and their impacts in designing recycle configurations in the SRU. Degassing sulphur directly in the SRU can minimise the amount of sweep gas required in downstream vessels and tankage as well as minimise potential for exposure to H_2S as sulphur is transferred.

Chemistry of sulphur degassing

Claus SRU rundown sulphur typically contains 200 to 600 ppm H_2S/H_2S_x. Higher concentrations are typical in the first condenser, dropping to lower levels in the remaining condensers. Oxygen enrichment tends to increase the amount of dissolved H_2S/H_2S_x present in the rundown sulphur stream.

The chemistry and mass transfer steps involved with degassing are as follows:

$$O_2\ (g) + S_8 \rightarrow O_2\ (\text{dissolved}) + S_8 \quad (1)$$

$$H_2S_X + ½O_2 \rightarrow S_X + H_20 \qquad (2)$$

$$H_2S + \tfrac{1}{2}O_2 \rightarrow \tfrac{1}{8}S_8 + H_2O \qquad (3)$$

$$H_2S_X/H_2S + \tfrac{3}{2}O_2 \rightarrow SO_2 + H_2O \qquad (4)$$

$$2H_2S + SO_2 \rightarrow \tfrac{3}{8}S_8 + 2H_2O \qquad (5)$$

$$\text{Stripping flow and agitation} \rightarrow H_2S, SO_2, H_2O, O_2, \text{stripping gas} \qquad (6)$$

The first step in sulphur degassing is that the oxygen (reaction 1) must dissolve in the liquid sulphur. Air is most commonly used as the source of oxygen in sulphur degassing, however other streams containing oxygen can be used. The partial pressure of oxygen or the pressure at which the degassing is taking place can dramatically increase this mass transfer step. This stripping gas is typically dispersed as fine bubbles to increase the mass transfer as well as to agitate the sulphur.

Polysulphide decomposition (reaction 2) is slow and therefore is more directly in control of the residence time required.

Typical product requirements for degassed sulphur are 10 ppm H_2S or less and this, in combination with the bubbling agitation employed, results in excess oxygen being present. As a result of this, some generation of SO_2 is also observed (reaction 4). With H_2S and SO_2 present, some Claus reaction (reaction 5) can also occur.

Once the above reactions have taken place, all of the gaseous products, must release from the liquid sulphur and are carried overhead with the balance of the stripping stream (reaction 6).

The interaction of sulphur viscosity and temperature must be addressed as part of the degassing process. Sulphur that hasn't been degassed has dissolved H_2S which has a suppressing effect of higher viscosities, however, as the H_2S is stripped, this suppressing effect is removed. There tends to be an optimum temperature to both promote mass transfer and maintain sulphur viscosity for optimal degassing rates. It is not uncommon that Claus SRU rundown sulphur is cooled slightly prior to degassing to optimise the holdup time required to achieve the degassed sulphur product H_2S specifications.

Inlet sulphur composition must be accurately known to size the degassing system. The degassing process can be viewed as a half-life process, where with higher inlet H_2S/H_2SX concentrations, addition residence time to run through additional half-lives are required to achieve the desired outlet concentration:

$$N(t) = N(0) * \left(\frac{1}{2}\right)^{\frac{t}{t_{1/2}}} \qquad (7)$$

Where:
$N(t)$ = final H_2S quantity remaining
$N(0)$ = initial H_2S quantity
t = time elapsed
$t_{1/2}$ = degassing half life

This can be rationalised in the doubling of time required to degas to outlet concentrations of 40 ppm + one half life → 20 ppm + one half life → 10 ppm + one half life 5 ppm, and so on.

It should be noted that degassing does not necessarily eliminate requirements for sweeping of downstream vessels or tanks containing degassed sulphur, as H_2S can build up in confined overhead volumes, even with little dissolved H_2S. Storing degassed sulphur, however, does greatly simplify vessel air sweep requirements and often allows for natural convection as well as venting to atmosphere.

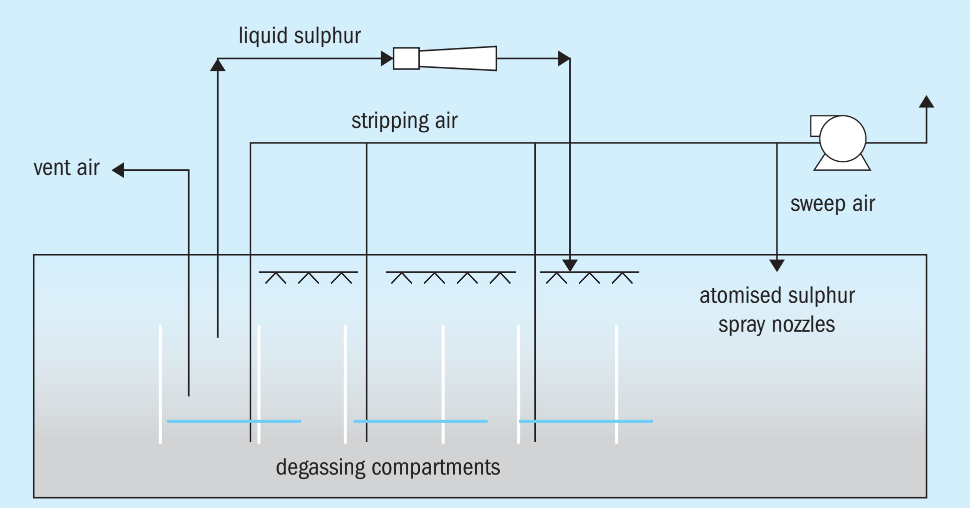
Degassing process historically

Historically, Claus SRU rundown sulphur has been collected in a below grade concrete sulphur pit, with internal steam coils for temperature maintenance and air sweep to maintain the vapour space at a comfortable margin below the lower explosive limit of H_2S. Sulphur degassing was located within the same pit, utilising air bubbled through the liquid sulphur pool for degassing. The degassing air stream combined with pit sweep air was routed to an incinerator via an eductor. In some cases, liquid sulphur was sprayed into the sulphur pit via a sulphur pump recycle to increase air contact and agitation. The working volume of these sulphur pits was typically set by the required degassing residence time, which was commonly in the 24 to 30 hour range.

This early in-pit degassing system resulted in a large sulphur volume/residence time and, as a result, a relatively large sulphur pit. Additionally, some segregation was required between the un-degassed and degassed sulphur sections of the pit. A large pit requires a correspondingly large pit sweep volume, which typically was sent to the incinerator, leading to increased SO_2 emissions. Fig. 1 shows a traditional in-pit sulphur degassing process.

Sulphur pits by nature are below grade and covered to contain H_2S off-gas. They are inhospitable places and not easily emptied for maintenance. The pits are of concrete construction and operate at elevated temperatures which leave themselves susceptible to corrosion from condensed water. Note that as they are below grade and operated at temperature, they experience thermal growth from initial construction, and therefore, from a cracking and corrosion standpoint, they are susceptible from both the inside (steam coil leaking) and outside (ground water). As the pit is difficult to empty, it frequently can collect debris from corrosion products and lead to subsequent pump problems.

Fig. 1: **Traditional in-pit sulphur degassing process**



Source: Fluor

When these SRUs go through a capacity increase, increasing the sulphur pit capacity is essentially impossible without significant capital expenditure. Often, the existing pit is utilised resulting in the pit residence time decreasing and as a result the existing in-pit degassing system is prone to underperformance.

Sulphur recovery units are changing

Sulphur recovery unit demands tend to change with time. For existing units, capacity increases are common and, with oxygen enrichment, capacity increases approaching 200% of original nameplate are common.

SRU SO_2 emissions requirements tend to become more stringent over time. Even without an SRU capacity increase, the addition of a tail gas treating unit (TGTU) can increase the sulphur recovery as the sulphur that previously went to the incinerator is now recycled to the SRU and recovered as liquid sulphur.

Nowadays, new sulphur plants being built increasingly take advantage of economy of scale of the petrochemical facilities they serve. Gas plant SRU capacities are increasing both due to the growing size of the facility and because they are being designed for much sourer feeds. It is not uncommon that these large facilities are measured in multiple trains of greater than 1,000 t/d sulphur product. Product sulphur requirements are <10 ppmv H_2S in the sulphur product as well as requiring tighter SO_2 emissions; these projects typically demand high sulphur recovery efficiencies which dictates that pit sweep and degassing unit vent streams are recycled to the SRU. Capex and opex are always at the forefront of decision making and the winning solutions are those with low lifecycle costs.

Modern degassing

Degassing providers are responding to the growing unit capacities, tightening project specifications, and optimised life cycle cost requirements. Owners are requiring systems that are less prone to corrosion, and easier to maintain.

Degassing licensors are or have developed processes that require shortened residence times which result in smaller equipment per unit throughput. Several licensors offer varying solutions:

- separate degassing vessel/out of pit degassing solution;
- degassing at pressure;
- solid catalyst;
- distributed catalyst.

The target of all of these degassing processes is to lower the overall lifecycle costs of operating the SRU. These degassing processes aim to decrease the residence time required to meet the residual H_2S concentration remaining in the degassed sulphur product.

Degassing processes that are favoured tend to have additional benefits over and above just the degassed sulphur product. These solutions are used both in new grassroots SRU facilities, and also as retrofit solutions where exiting brownfield sites require increased capacity and are looking at innovative approaches rather than outright replacement with greater equipment sizing following the historical methodologies.

Reduced residence time to meet product sulphur requirements using an advanced degassing process allows existing equipment to process greater throughputs or, in a grassroots project, allows optimisation of the degassing process resulting in numerous benefits:

- Reduced cost of smaller equipment with equal or better process throughput capacity.
- Sulphur pits sizing is switched to that required for operation flexibility versus that of being bound to the traditionally 24-30 hours residence time because of the legacy degas process. Many operators are utilising 4 to 8 hour holdup capacity to address operational flexibility/equipment out of service, without having to be constrained with the traditional degassing residence time.
- Smaller equipment volumes require smaller pit sweep flowrates.
- Many operators are choosing to eliminate the sulphur pit completely with these reduced holdup volume requirements. Sulphur rundown storage is typically now favourably addressed via a vessel in a below grade vault. The vessel is below grade to allow for gravity drainage of rundown sulphur. The rundown vessel is externally steam traced/jacketed which greatly reduces the likelihood of a steam coil leaking directly into the process. The vessel is not exposed to a buried environment and as such ground water, corrosion and lack of ability to inspect are removed from the typical sulphur pit.

Simplification of implementation

What sets degassing processes apart is simplicity and cost effectiveness of their implementation. Sulphur degassing is not an isolated process; it requires integration into the SRU. It receives feed from the SRU and requires a destination for the degas H_2S vent stream as well as the product degassed sulphur stream. This is even more important in large scale SRUs. Degassing processes that allow economy of scale further improve overall cost effectiveness.

As stated before, the reduction of residence time or holdup volume for the degassing process allows the sulphur rundown storage volume to be sized for a requirement other than degassing residence time. In retrofit solutions this may allow use of the existing pit with greatly higher sulphur production values. For new facilities this allows for a tighter plot plan and reduced construction quantities.

Out-of-pit degassing solutions allow for a purpose built degassing vessel which opens up several potential optimisations. An out-of-pit degassing solution can be unique to an individual SRU or common to multiple SRU trains. The existing or new much smaller forwarding pit(s) can route un-degassed sulphur to a common shared degas system. An out-of-pit solution can be modularised to allow cost effective construction and a quick turn-around for tie-ins to the overall facility.

A common degassing process servicing multiple SRU trains may allow simplification of the degassing H_2S vent stream. This potentially avoids the need to duplicate the entire degassing H_2S vent system in each SRU train. The degassing vessel can be co-located with the thermal reactor/incinerator allowing for short vent piping. Less piping results in less utilities requirements to keep the vent heated, shorter lengths of piping minimise maintenance as there is less material to corrode or sections of piping to plug with sulphur.

Another simplification for degassing processes is to avoid duplication of degassed sulphur storage. From an economy of scale standpoint an offsite storage tank is much more cost effective with regard to cost of storage per volume of storage. The sulphur product eventually needs to get to the final storage location for loading to transportation, pipeline or forming of solid pellets. The fewer number of vessels between the final sulphur destination reduces the number of sweep gas streams and emissions points.

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Technology pros and cons

Evaluation criteria are presented in this section to allow the user to determine the pros and cons of various technologies associated with their project. Project specific criteria or interfaces may simplify or complicate specific aspects of any technology and are addressed with respect to integration to the balance of the facility. Specific technologies are not discussed; however, several criteria are presented to facilitate selection.

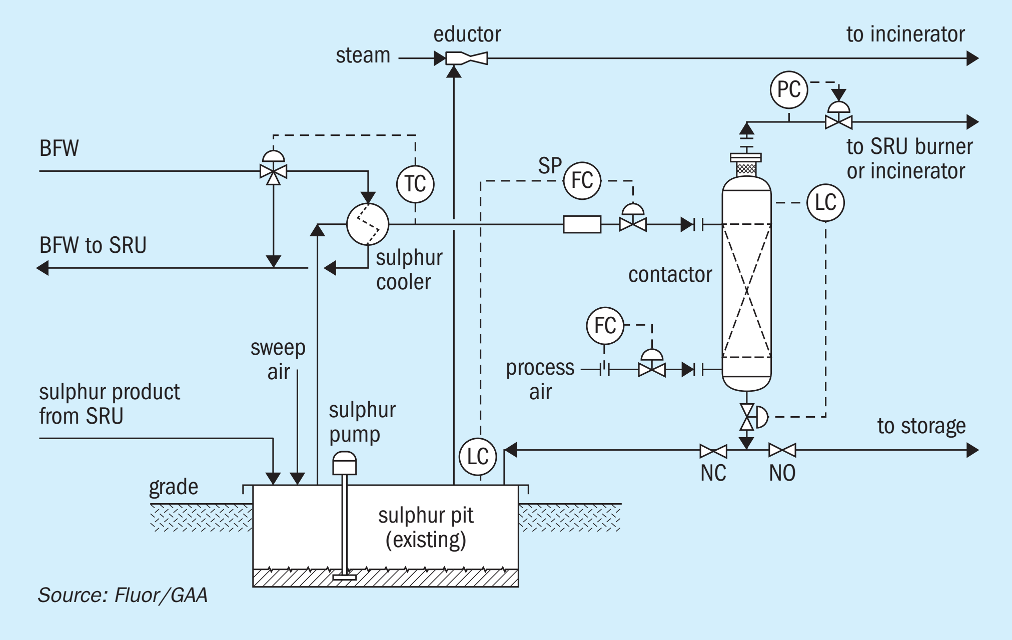
Cost: Cost is usually one of the more significant criteria used in the technology evaluation. Cost should include both capital cost as well as the operating cost. This can be one of the more difficult criteria to evaluate as degassing technologies need to be integrated into the overall SRU. Evaluations to consider are how much equipment is required to implement? Are there changes to the existing SRU process that are required in order to integrate the technology? What utilities and in what quantity are required for the technology? If a technology uses a specific utility or piece of equipment that is at capacity in an existing facility, there is potentially a step change in cost required.

Experience base: What is the history of the technology? Does it have a wide experience list with hundreds of installations or is it just emerging with limited commercial implementations? Ask to see an experience list with project details similar to yours.

Degassed product spec requirements: What is the required product sulphur H_2S residual? While the most common degassed sulphur specification is less than 10 ppm H_2S residual, it is not the only requirement. If there is some flexibility in product specification, particularly in retrofit situations a specific technology may minimise the amount of work and cost required to implement.

Simplicity of operation/equipment complexity: How complex is the process? Does it use simple equipment and controls or are they complex? Simple processes use known equipment and controls, preferably existing equipment/controls for a retrofit installation. As an example, are additional pumps required for the process; can it use existing pumps or are no pumps required if the pressure profile allows available pressure to be utilised.

Fig. 2: **Typical D'GAASS process flow diagram**



Source: Fluor/GAA

Integration into the overall SRU process: The actual degassing process needs to be understood, but also the impact to the SRU for the feeds/utilities to the degassing process as well as the product sulphur and overhead vent stream. Controls permissives and interlocks impacting the overall integration should be evaluated as well; Does the degassing technology simplify or complicate the operation of the associated SRU?

Consumables/catalysts: Does the process require catalysts and if so are they continuously added? How long does the catalyst last and what is performance as catalyst degrades? Is there operational experience with this at other similar sites? Contrast this to a process that exploits simple operating parameters such as temperature and pressure which are easily manipulated and understood by operations.

Lessons learned: Does the technology supplier have any lessons learned of the process? What were the solutions implemented? Are the lessons learned one-off or perhaps individual site mis-operation. Does the technology supplier readily share the lessons learned to avoid repeat at your site?

Ease of retrofit if implemented to existing SRU: How complicated is the integration of the technology to the existing plant? Does it require extended shutdowns to interconnect? For example, are the interconnections simple piping connections or do they require shutdown and work inside the sulphur pit? Consider the feeds, vent streams, product streams as well as any utilities. What is simple in one facility may be very complicated in another facility.

D'GAASS process implementation in a large scale SRU facility

This section reviews the Fluor/GAA D'GAASS process specifics and highlights scale of economy benefits with installation in large SRUs.

There are currently more than 140 D'GAASS units operating around the globe with utmost reliability and availability/onstream time. Individual installations range in size from 10 t/d to sites with multiple units as large as 2,500 t/d capacity each. Installations typically include a D'GAASS unit per SRU train, however, frequently a single common D'GAASS unit serves multiple SRUs. The D'GAASS process consistently achieves less than 10 ppmv residual H_2S in the degassed sulphur. A typical D'GAASS process flow diagram is shown in Fig. 2.

The D'GAASS process countercurrently contacts liquid sulphur with dry process air at pressure. Higher pressure operation significantly accelerates sulphur degassing as the partial pressure of oxygen is higher and therefore promotes the decomposition of polysulphides as well as H_2S. Air is introduced at the bottom of a vertical column and is distributed across the column where it contacts un-degassed sulphur introduced at the top of the vertical vessel. As the air bubbles rise in the contactor, they promote both the degassing reactions as well as stripping the H_2S into an overhead vent stream. For optimal degassing, un-degassed sulphur is cooled to 135°C prior to entering the vertical contactor column. Sulphur residence time in the contactor is approximately 1 hour and 10 ppmv residual H_2S or less is guaranteed.

Integration into both existing SRUs and new SRUs is greatly simplified due to the pressurised contactor operation. Both the overhead vent stream and the degassed liquid sulphur stream are at pressure. Contactor overhead vent gas can therefore be pushed to the SRU thermal reactor by pressure differential via simple control valves. Similarly, the degassed liquid sulphur product can be pressured to degassed sulphur storage without the use of pumps.

Feed from the SRU sulphur rundown pit is usually pumped. Typically, existing sulphur pit pumps have sufficient pressure for direct use by the D'GAASS process and can be used without modification. Because the sulphur degassing occurs in the out of pit contactor, there is no longer a 24-30 hour residence time requirement for the sulphur pit as for traditional sulphur degassing processes (see Fig. 1). As a result of this, the sulphur pit storage volume is independent of the degassing residence time requirement. Many of Fluor's clients in new installations prefer a sulphur storage vessel configured in a concrete vault in lieu of the traditional, maintenance intensive concrete pit. In this configuration, a small horizontal vessel, with external heat tracing or jacketing, is in a much more maintenance friendly configuration which eliminates internal steam coils and the potential for corrosion from water (both internally and externally to the vessel).

The D'GAASS process is compact and can be easily modularised. Fig. 3 shows a typical prefabricated D'GAASS module ready for shipment and Fig. 4 shows the module in vertical orientation.

The vertical configuration of the contactor vessel allows for very efficient use of the stripping air as it is completely countercurrent to the sulphur stream. Horizontal vessels typically use multiple packing columns and require multiples of stripping air to feed each individual packing column. This additional stripping air increases the size of the reaction furnace and incinerator as well as increasing the utilities requirement for horizontal configuration arrangements.

The D'GAASS contactor effectively eliminates corrosion utilising a jacketed vessel. The overhead vent stream which contains H_2S, O_2, H_2O, SO_2 as well as other inerts present in the process air stripping stream equipment and piping needs to be maintained hot to avoid wet/sulphurous acid corrosion. The contactor vapour space and overhead vent lines are jacketed with slightly higher pressure steam to keep water in the vapour phase. Experience has shown this to be a very effective method of minimising corrosion.


PHOTO: FLUOR

Fig. 3: Prefabricated D'GAASS module ready for shipment


PHOTO: FLUOR

Fig. 4: D'GAASS module in vertical orientation

The sulphur cooler can utilise a variety of cooling streams. Use of boiler feed water allows the cooling sulphur to preheat boiler feedwater which improves overall energy efficiency of the SRU. An alternative, such as a steam reboiler with a separate waste steam condenser, allows the sulphur to be cooled to the optimum temperature without the complication of heat integration of other streams.

The D'GAASS process is very cost effective with increasing sulphur degassing capacity. Increased capacity is accommodated by increased contactor diameter while maintaining the overall contactor height. Again, typical contactor residence time requirement is approximately one hour; the volume of the contactor increases as the square of the diameter. Similar economy of scale benefits result from the efficient vertical orientation of the contactor vessel and the counter current air stripping stream flow configuration.

Alternative stripping streams can be used if spiked with oxygen. This alternative allows the D'GAASS process to be used in a CO_2 capture configuration where air is substituted with a CO_2/O_2 mixture, again at pressure. Recycling of this CO_2/O_2 degas overhead stream to the reaction furnace prevents nitrogen introduction into the thermal reactor tail gas when 100% oxygen enrichment is utilised.

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Rejuvenation of a vintage SRU

In this revamp case study **Scott Kafesjian** and **Quinn Kotter** of Wood demonstrate how Wood sulphur technology was implemented at a 46-year old refinery SRU to improve reliability, operability and performance to meet new requirements for increased flexibility and higher availability.

A recent revamp project executed by Wood was contracted by a North American refiner with two operating SRUs – SRU A, dating to 1974, and SRU B, a modular unit, designed and delivered by Wood in 2006. Each SRU included a 3-reactor Claus section, incinerator, and caustic scrubber. Having installed a NaHS (sodium hydrosulphide) unit in 2013 to treat another sour gas stream, SRU A became a non-essential unit, only maintained for safe operation, with minimal investment otherwise.

A recent change in the refinery operating strategy elevated the importance of SRU A due to higher projected crude throughput and sulphur content. Accordingly, SRU A capacity was projected to become essential and high availability was required to enable the desired future operation of the refinery.

Major investment in sulphur units (usually regarded as cost centres) is difficult to justify, which is why SRU A had been somewhat neglected, but the revised strategy motivated and justified the revamp project.

Background

It was clear that with the escalated role of SRU A, a revamp would be necessary; however there were many known issues to overcome to meet the future demands, including:

- the thermal stage was inadequate to process sour water stripper acid gas; only amine acid gas could be fed;
- an obsolete, maintenance intensive, difficult-to-control reactor reheat scheme was in place;
- the 3rd Claus reactor became inoperable early in the life of the unit and subsequently had been completely bypassed;
- the sulphur pit concrete was severely degraded and excessive fugitive emissions were present;
- the burner management system (BMS), although functional, was antiquated and obsolete;
- air flow to the SRU was manually controlled due to an inoperable air demand analyzer (ADA);
- excessive CO emissions from an undersized quasi-natural draft incinerator;
- severe corrosion due to caustic carryover from the tail gas SO_2 scrubber to downstream equipment.

Long-term improvement to SRU A was needed to ensure that it could reliably meet projected refinery sulphur production and serve as a backup to SRU B.

The revamp scope was identified in the bidding stage as:

- replace end-of-life/obsolete equipment;
- eliminate the ineffective reactor reheat scheme;
- recommission the No. 3 Claus reactor;
- replace the ADA and stack CEMS;
- replace local burner control panel with SIL2 rated, remote PLC;
- eliminate corrosion issues related to the SO_2 scrubber.

The process scheme prior to the revamp is shown in Fig. 1. Highlights of the configuration include:

- an obsolete acid gas burner and single chamber thermal reactor;
- two-pass waste heat boiler developing steam at 250 psig with sulphur rundown connections;

Table 1: **Turnaround findings and resolution**

Item	Finding	Likely cause	Action
Thermal reactor refractory	Degraded	High temperature, rapid temperature changes	Repair
Thermal reactor shell	Wall thinning	Acid dew point corrosion	Repair/patch
Thermal reactor shell	Wall bulge	High temperature exposure	Repair/patch
Acid gas burner	Tip damaged	High temperature exposure	Replace tip
Waste heat boiler	Tube wall thinning	High temperature exposure, corrosion	None, acceptable Replace inlet ferrules Replace tubesheet refractory
Gas/gas heat exchanger	Tube leaks	Acid dew point corrosion	Plug leaking tubes at ends
Booster blower	Corrosion	Acid dew point corrosion, caustic carryover	None
Stack refractory	Extensive damage	Temperature cycling	Partial repair
Stack wall	Corrosion	Acid dew point corrosion	Repair

Source: Wood

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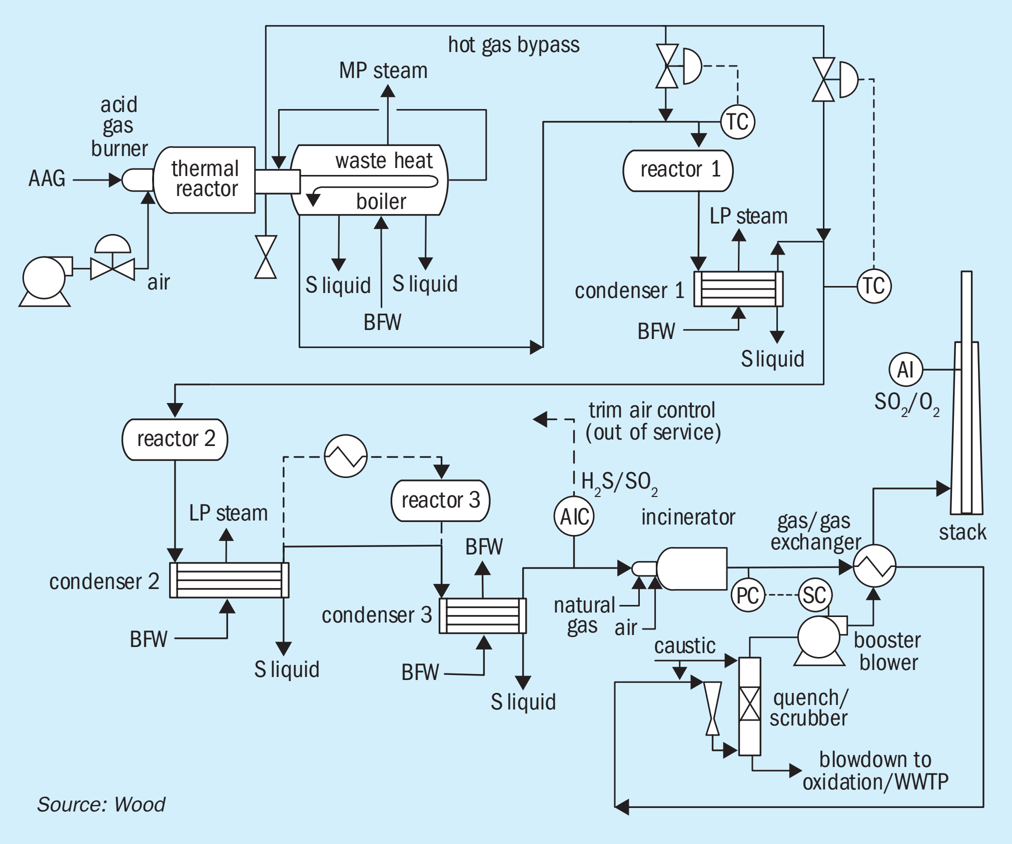
- hot gas bypass reheat scheme for the No. 1 and No. 2 Claus reactor inlet streams (where the "hot gas" consists of a portion of the thermal reactor effluent mixed with a portion of the first WHB pass effluent);
- the 1st and 2nd sulphur condensers were in a common shell (developing 40 psig steam) and the 3rd sulphur condenser was a BFW heater in a separate shell;
- the No. 3 Claus reactor had been bypassed (piping removed) and abandoned in place;
- the ADA was out of service and air control was manually adjusted based on acid gas feed rate and caustic consumption over time;
- a quasi-natural draft incinerator located after the No. 3 sulphur condenser, followed by heat exchange to scrubber effluent upstream of the stack;
- after heat recovery, incinerator effluent was further cooled in a venturi quencher then entered a packed bed caustic scrubber for SO_2 removal;
- sulphites in the scrubber blowdown were oxidised and routed to the refinery WWTP;
- a booster blower downstream of the scrubber was used to control incinerator outlet pressure to maintain draft;
- booster blower outlet was heated against incinerator effluent and routed to atmosphere via the stack.

At the start of the project, it was anticipated that there would be additional scope developed since a unit turnaround was scheduled to begin shortly after project kick-off. Inspections planned during the turnaround were expected to result in additional "discovery" scope.

The project scope also included consideration of improvements to safety, reliability, performance and operability leading to recommendations to the owner. Recommendations would be evaluated based on technical justification and their estimated cost. Numerous improvements were recommended by Wood based on process evaluation and turnaround findings.

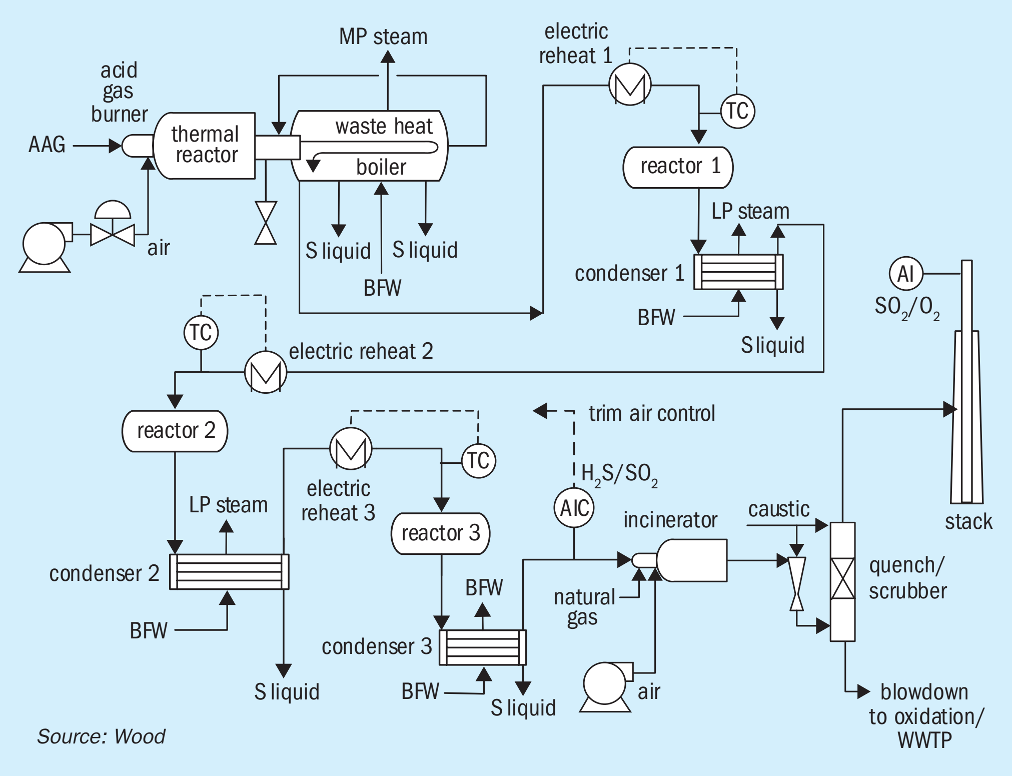
Post-turnaround, it was known that the unit would need to operate for about two years before the revamp could be implemented during the next planned unit shutdown.

Fig. 1: **Pre-revamp configuration of SRU A**



Source: Wood

Fig. 2: **Post-revamp configuration of SRU A**



Source: Wood

Scope evolution

Table 1 summarises turnaround findings and the proposed interim action before the revamp.

In the early phase of the project Wood recommended several key process configuration changes in addition to the initial known revamp scope:

- eliminate gas/gas heat exchanger;
- eliminate booster blower;
- replace induced draft incinerator with forced draft design capable of improved control, higher operating temperature and increased residence time;
- route incinerator effluent directly to quencher;

- replace quencher with new venturi with upgraded MOC designed for higher inlet temperature;
- replace scrubber packing with more efficient, lower pressure drop packing;
- replace degraded stack with higher metallurgy, smaller diameter stack supported by existing structure;
- include an engineered external thermal protection system (ETPS) for the thermal reactor;
- improve thermal reactor air flow control algorithm to stabilise operation and utilise the new ADA output;
- replace sulphur pit with an above-grade sulphur header and storage tank.

Fig. 2 shows the configuration of SRU A after the revamp. Highlighted changes to the unit configuration include known owner defined changes/additions and Wood's recommended changes/additions.

Wood also recommended complete replacement of the waste heat boiler; however, this was not approved due to high cost, lack of plot space, and turnaround findings showing acceptable remaining life of all components.

Challenges

As the project progressed through the stage gate process (FEL-1/2/3), several challenges were encountered.

Unit location: Being an older unit located near the refinery boundary, the unit was restricted by roads on three sides and an operating unit on the fourth side, rendering plot space very limited. Existing equipment was tightly spaced. Existing utility piping was a mix of active and inactive lines, without clear status documentation.

Sulphur product collection: A significant challenge was that limited elevation was available for sulphur rundown line routing to allow product collection by gravity flow. Both sulphur condensers and the WHB remained at their original location and elevation. The condensers were adequately elevated for proper line routing. The most difficult sulphur collection location was the sulphur outlet from the second pass of the WHB, which was the farthest from the new sulphur header and at the lowest elevation. Enabling gravity drainage required replacing the existing vertical sulphur outlet nozzle with a nozzle oriented tangentially to the bottom of the outlet plenum (Fig. 3). Sulphur seals on all rundown lines were specified with zero elevation change from inlet to outlet (Fig. 4). Furthermore, minimal slope of rundown lines was specified (1/8" per foot of running length). The collection header was set at minimum elevation above grade as the owner did not allow below grade installation.

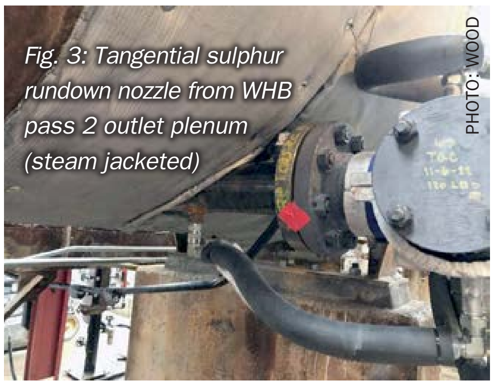


Fig. 3: Tangential sulphur rundown nozzle from WHB pass 2 outlet plenum (steam jacketed)

PHOTO: WOOD

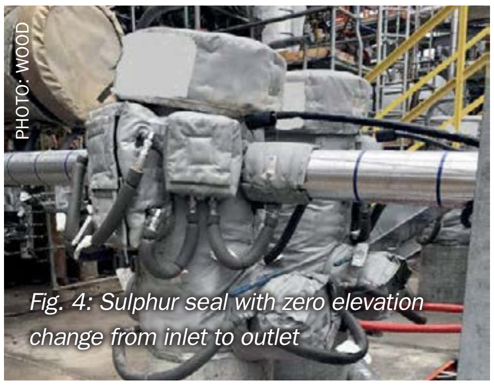


Fig. 4: Sulphur seal with zero elevation change from inlet to outlet

PHOTO: WOOD

Pandemic: Part way through the project, COVID-19 became a household word and the "new normal" way of working had to be defined, accepted, and complied with while minimally disrupting project progress.

Scope additions and changes were common as the owner and Wood identified and sorted out various "want to have" and "must have" items. This working environment required a nimble project team, constant attention to agreed scope, timely communication between owner and engineer, and a steady stream of change notices requiring preparation, review, and approval.

Restore SWSG feed: A major addition to the revamp scope took place after completion of detailed engineering based on owner philosophy change – the unit was to be able to process sour water stripper acid gas feed to in the event that SRU B was completely out of service. This change necessitated the following additions:

- restore SWS KO drum;
- replace the feed piping for SWS gas and add piping for amine acid gas rear chamber split;
- include flow measurement and control for SWS gas;
- preheat both acid gas feed streams (accomplished with engineered external heating elements);
- revision of thermal reactor vessel and ETPS size;
- refractory and checker wall revisions;
- thermal reactor temperature measurements (internal and external).

Unit sulphur production capacity is reduced when SWSG is fed, so there was a derate of unit capacity. Nearly all aspects of the design had to be checked to assure there was no impact due to SWSG processing.

Project progression

The overall project duration from award to introduction of acid gas feed was 47 months. The discovery turnaround occurred about three months after project award, simultaneous with the FEL 1/2 effort and Wood's process evaluation and reconfiguration recommendations. FEL 3 was completed and detailed engineering began about six months after award, followed by equipment bidding and order placement in the following months. Shortly thereafter, Covid protocols were initiated, inevitably slowing progress as the owner, Wood, and vendors adjusted to the global supply chain impact. As a result, detailed engineering duration was months longer than originally planned. Shortly after detailed engineering completion, addition of SWSG processing was requested and additional design work began as a result.

Wood was not directly involved in the construction activities, however, Wood provided support during commissioning, pre-startup checkout, and startup. Successful start-up of the unit was accomplished, and early performance indicates significant operating cost savings are realised from greatly reduced caustic consumption in the scrubber due to improved sulphur recovery in the Claus section.

Summary

A change in refinery strategy placed increased importance on the availability, controllability, performance, and safety of an existing 46-year-old SRU.

The many benefits of Wood sulphur technology improved reliability, availability, efficiency, and performance, reduced maintenance and improved safety, while meeting owner requirements, and enabling SRU A to fulfil its elevated role in the refinery. ■

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60 years in the sulphuric acid industry

For six decades, Chemetics has been a pioneering force in the sulphuric acid design and equipment industry, consistently introducing groundbreaking technologies that have revolutionised the field by optimising the methodology in which chemicals are produced. This year, Chemetics celebrates its 60-year anniversary as one of the leading designers, direct equipment suppliers and fabricators that has modernised the sulphuric acid industry of today. This article dives into Chemetics' rich history and key innovations that have shaped and moulded the industry.

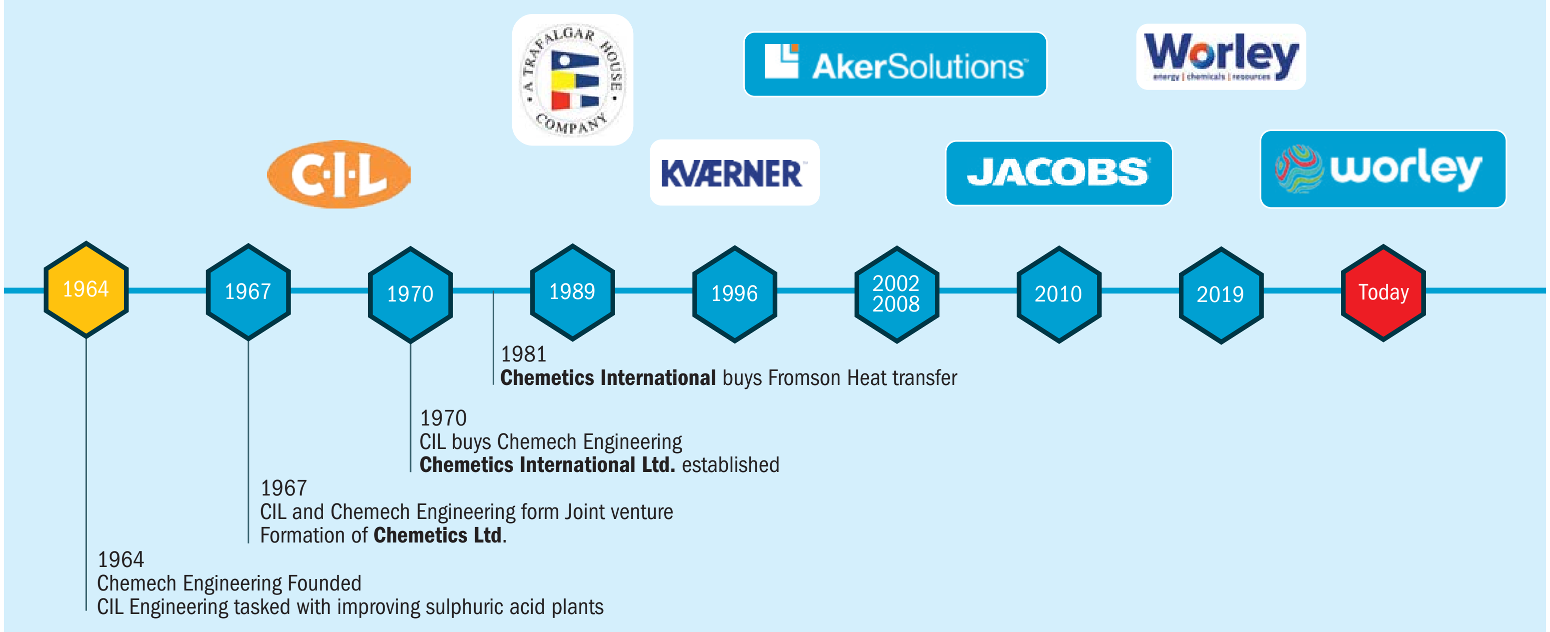
A brief history

Chemetics Chemetics Inc. began its journey on 2 March 1964 as Chemtech Engineering, specialising in sodium chlorate electrolysis and in the pulp and paper industry. In 1967 CIL (Canadian Industries Limited), which was majority owned by ICI of the UK and Chemetics Ltd, banded together to form a joint venture to market the chlorate technology. During this time, the experts at CIL invented the anodically protected shell and tube heat exchanger, originally known as the "CIL cooler", which was marketed through the joint venture and that transformed the sulphuric acid industry. In September 1970, Chemech Engineering was purchased by CIL and in 1971 changed the name to Chemetics International Company Ltd. Over the next two decades, Chemetics International Ltd introduced new lines of proprietary equipment which would set the foundation and change the way sulphuric acid plants are designed today. In 1981, the company also had the foresight to purchase the fabrication facility, Fromson Heat Transfer, that had been producing the anodically protected acid coolers for Chemetics since their inception. This marked the beginning of the close cooperation between engineering and design and the fabrication that continues until today.

In the 1980s, Chemetics marketed and sold its new technology and equipment to the sulphuric acid industry expanding its market base offerings, while taking on new and exciting projects domestically and internationally. On 1 November 1989, ICI Chemicals Plc, the UK parent of CIL, sold Chemetics to Trafalgar House Plc, a UK holding company with headquarters in London. Chemetics then became part of John Brown E&C, the engineering division of Trafalgar House.

In the 1990s, Chemetics continued to expand its technology, equipment and plant sales worldwide. In 1992, Chemetics consolidated its acid business

Fig. 1: **History of Chemetics**



Source: Chemetics

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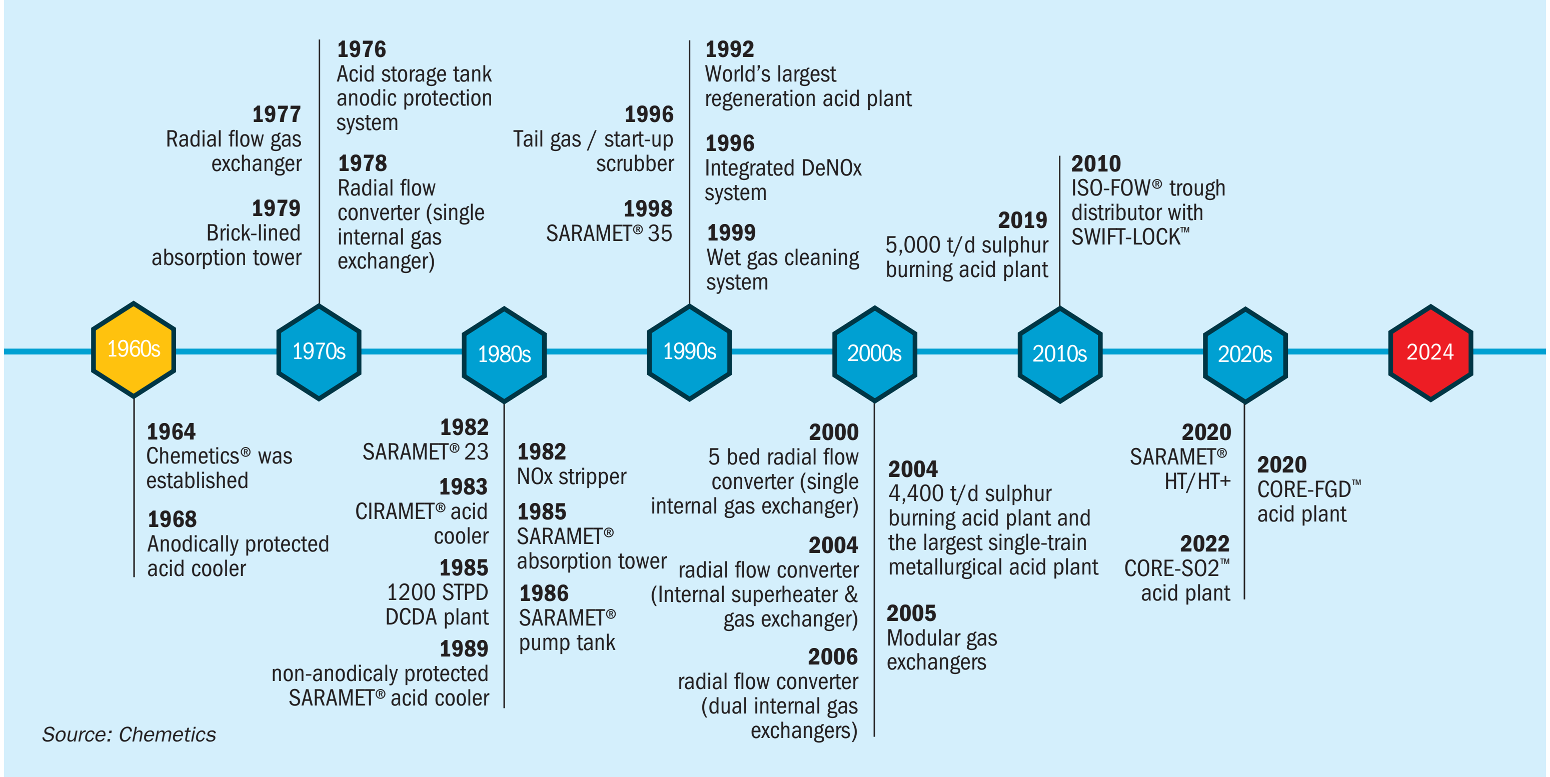
Fig. 2: **Key innovations and modern advancements**



Source: Chemetics

and operation in Vancouver. In 1996, Trafalgar House was purchased by Kvaerner ASA, Norway's largest privately held company. Chemetics, as technology supplier, maintained its independence, a common theme seen throughout the rest of the acquisitions.

In 2001, Kvaerner Chemetics became integrated with the rest of the Kvaerner group when Aker Maritime, another large Norwegian company, took over the leadership role within Kvaerner.

Chemetics in the 2000s continued to expand its market and develop new technologies. These years proved pivotal for Chemetics as different approaches in both technology offerings and commercial offerings were explored.

In 2009, Chemetics opened a new 90,000 square foot modern fabrication shop specialising in high alloy fabrication to continue to supplement the technology and engineering supply of Chemetics Inc. This replaced the existing fabrication shop that was purchased in the 1980s.

In 2011, Jacobs Engineering group acquired Aker Solutions Canada Inc., along with the entire P&C group of Aker. Chemetics, again being the technology supplier and having already 50 years' worth of experience in the industries it served, kept its name as a specialised entity. Jacobs Engineering subsequently sold its entire ECR business, including Chemetics, to Worley Parsons in 2019.

Within the Worley organisation, Chemetics Inc. (branded as Worley Chemetics) is currently part of Worley's Technology Solutions group focused on technology offerings to its global clients. As part of the greater Worley Group, Chemetics has enhanced its global presence through the potential use of the local area offices, allowing for local support.

Since 2023 Chemetics has been rebranded as Worley Chemetics, but remains the same entity that has enabled it to thrive over the last 60 years. Chemetics still incorporates the innovative spirit that has led it to where it is today, supplemented by the experience gained over the course of many executed projects over its existence. Chemetics' ability to retain its brand name and recognition over the course of 50 years of acquisition and sales speaks volumes for the quality and brand recognition in the sulphuric acid industry.

Key innovations and modern technological advancements

Chemetics has been and continues to be a pioneering force in the advancement of sulphuric acid plant technology and sodium chlorate electrolysis today. These advancements are a direct result of its customers' needs for better emissions, higher capacities, longer campaigns, and fewer unscheduled shutdowns. Chemetics within the sulphuric acid industry has been able to service its clients whether they are producing acid via burning sulphur, capturing SO_2 offgas from a metallurgical operation, or regenerating/concentrating acid from weak acid streams. Within each industry the need for innovation has been driven by the requirement to increase value for its customers and provide maximum reliability of operation. Fig. 2 shows a snapshot of Chemetics' key innovations over the decades.

Acid cooler

In 1967, CIL and subsequently, Chemetics Inc. revolutionised the sulphuric acid industry by the invention and installation of the anodically protected (AP) sulphuric acid cooler. This proprietary piece of equipment can be considered a founding product as it enabled Chemetics to become the company it is today. Few developments within the acid industry can claim that they changed the industry as much as the Chemetics acid cooler. The Chemetics acid cooler replaced the ductile iron serpentine coil acid coolers that were prone to failure and took up a huge footprint area of the plant. The Chemetics AP cooler reduced the size of the equipment by 80+%, increased longevity and was virtually maintenance free. These proprietary pieces of technology are manufactured to the highest standards in Chemetics' shop to enable direct quality control over the fabrication, ensuring a consistent and

Fig. 3: Chemetics AP acid coolers

reliable product every time. The AP acid cooler, while developed in 1967, has continued to adapt to client requirements over the course of the decades to become what it is today, incorporating new process design criteria, materials of construction, thermal designs, manufacturing details and improved electronics. One such key component that allows for life spans of over 30 years is the ANOTROL system designed in 1970, which is Chemetics' electrical/electrochemical corrosion control system used to protect the acid coolers from acid corrosion. Each new generation of ANOTROL system has been custom designed based on the experience of the previous version and as such the new ANOTROL 20/20 system provides an even wider range of capabilities.

Stainless steel converters and radial flow gas exchangers

In 1980, Chemetics introduced the first iteration of the fully welded stainless steel converter, which forms the heart of the acid plant today. The converter design replaced the old grid-and-post catalyst support beds, brought a different nozzle arrangement and incorporated a design philosophy to reduce maintenance and expand converter longevity. The design philosophy was such that there would be no flat surfaces making all components round, curved, or dished to reduce overall stress. The converter incorporated a central core allowing for internal exchangers to be installed, reducing the need for an external gas exchanger and allowing for modular fabrication. The converter was fully welded and manufactured out of specific controlled stainless-steel chemistry chosen for the application. It was the first stainless steel converter in the acid industry. These design conditions have allowed the converter to last for longer than 30 years without major repairs. Over the decades, advancements have been made to the design bringing the Chemetics converter to what it is today, allowing for massive converter constructions for capacities of even 5,000 t/d. Leak free operation for decades is the norm for Chemetics radial flow converters.

Alongside the push of stainless-steel components into the acid plant, modernising them to today's standards, Chemetics also introduced the stainless-steel radial flow gas exchanger in 1979, installing over 400 worldwide since its inception. These patented designs followed a radial pitch tube layout allowing for a better overall thermal design with improved thermal efficiency creating a constant mass velocity between the tubes. It allows for a smaller sized exchanger saving on footprint and space. The radial gas flow pattern minimises thermal stresses across the bundle by eliminating temperature variation and differential thermal expansion, leading to longer life and virtually zero leaks. The requirement of welding the tube-to-tube sheet joints on both tube sheets also ensured leak free life for the exchangers and allowed changes in the plant flowsheets to allow greater heat recovery and lower stack emissions.

SARAMET™

The introduction of the Sulphuric Acid Resistance Alloy METal (SARAMET©) a high silicon stainless steel material that allows for direct metal to sulphuric acid contact at any velocity was introduced and patented in 1982. The first introduction of SARAMET 23 allowed for fully welded piping systems significantly improving safety. Shortly after, full alloy related equipment including absorbing and drying towers, distributors, internals, tanks, coolers, etc. were introduced. Innovations to the metallurgy have not stopped with the addition of grades of 25 in 1990, 35 in 1998, HT in 2018, and HT+ in 2020, each specifically designed to be used in a specific range of acid concentration and operating temperature while being cost conscious.

Fig. 4: Chemetics radial flow stainless steel converters


PHOTO: CHEMETICS

Fig. 5: Chemetics SARAMET™ absorber tower

Drying and absorbing towers

In 1982, with the introduction of SARAMET material to the market, Chemetics was able to utilise the benefit of the material to provide other key parts of the acid plant such as alloy towers starting from 1986. This edition to the family of equipment allowed for easier retrofit projects that reduced the overall construction length on site and reduced shutdown modifications ultimately lowering the total installed costs. The drying and absorbing towers brought key advancements to the industry such as how the gas nozzle inlet is fabricated and protected, how the packing support functions to reduce overall pressure drop of the tower, the self-supported distribution system that evenly irrigates the acid flow throughout the transfer bed and gets rid of unnecessary hangers, and the uniquely designed candle plate housing the candles used to filter acid mist and droplets. These design additions changed the way that alloy acid towers were designed. The attention to the design details in Chemetics towers has virtually eliminated localised corrosion issues that plague some other designs.

Chemetics also introduced some key design changes to how brick-lined towers are constructed, such as the use of a fully self-supported ceramic packing dome, multi-layered special shaped acid-resistant brick backed by a PTFE membrane insert, the dished bottom down to prevent brick heaving, and how the nozzles are packed, resulting in over 25 years of service.

Strong acid distributors

The next instance of utilising SARAMET came into effect in 1983 when Chemetics started introducing the SARAMET material to replace the common ductile iron pipe distributor. This was the first advancement made in this area and it wasn't until 1995 that Chemetics delivered its first SARAMET© trough distributor design, which was a welcomed change compared to the original pipe distributors, simplifying the irrigation portion of the acid. The ISO-FLOW™ trough distributors featured an orifice design, which allowed uniform flow and control through each downcomer tube, allowing for better absorption and for flow imbalances, if any, to be visually seen and adjusted easily. The calming plates with integral screens filter out any packing chips or debris and eliminate the need for an acid strainer upstream. The ISO-FLOW design creates a calm liquid surface of acid within the trough ensuring even flow to each downcomer. Diagnosis of plugged or partially blocked tubes is simple with a flow test ensuring that the distribution will be optimal after every plant cold shutdown. Expanding on the notion to reduce site installation and maintenance time, Chemetics in 2016 designed the SWIFT LOCK™, which simplifies attaching the downcomer tube banks to the main trough, making installation of the already fully fabricated (expanded and seal welded) tubes onto the distributor with preinstalled attachment brackets. This reduced the overall installation time by 90% and helps with any future plant shutdowns. The distributors can easily be disassembled and removed from the towers and later reinstalled if desired. This can greatly simplify tower maintenance. Chemetics has supplied over 150 of these ISO-FLOW™ with SWIFT-LOCK™ distributors in various different SARAMET alloys.


PHOTOS: CHEMETICS

Fig. 6: Chemetics ISO FLOW™ SWIFT-LOCK™ SARAMET distributor

Modular equipment

Clients with their ever-expanding need for capacity were demanding larger and large pieces of equipment forcing site assembly due to transportation corridor limitations to the site. Transfer of the shop fabrication scope to field assembly became an issue due to the unpredictability of weather events, assembly at heights and consistent site construction cost overruns. Chemetics met this challenge by redesigning the large equipment into modules where the goal was to complete as much pre-fabrication, especially of the complex portions, in a controlled shop environment and then just assemble the modules together on site like a series of building blocks. This approach ensures high quality of the end product and minimises field costs. Modular gas to gas exchangers have been shipped worldwide, converters are assembled in a fraction of the time, modular acid alloy towers are constructed on site all with the assistance of Chemetics construction experts.

Gas cleaning

In metallurgical operations the requirement for gas cleaning prior to the contact plant is an absolute requirement as the hot and dirty gases arising from the smelting operation need to be cleaned and conditioned prior to any further processing. Traditionally equipment used in the hot, cold, or wet gas duties was fabricated out of carbon steel and then loosely lined with lead for corrosion protection followed by acid brick lining to protect the lead lining. This led to problems such as the difficulty in identifying leaks, fluoride attacks, cracks due to pressure cycling, and ultimately

PHOTOS: CHEMETICS

Fig. 7: Chemetics modular radial flow stainless steel converter

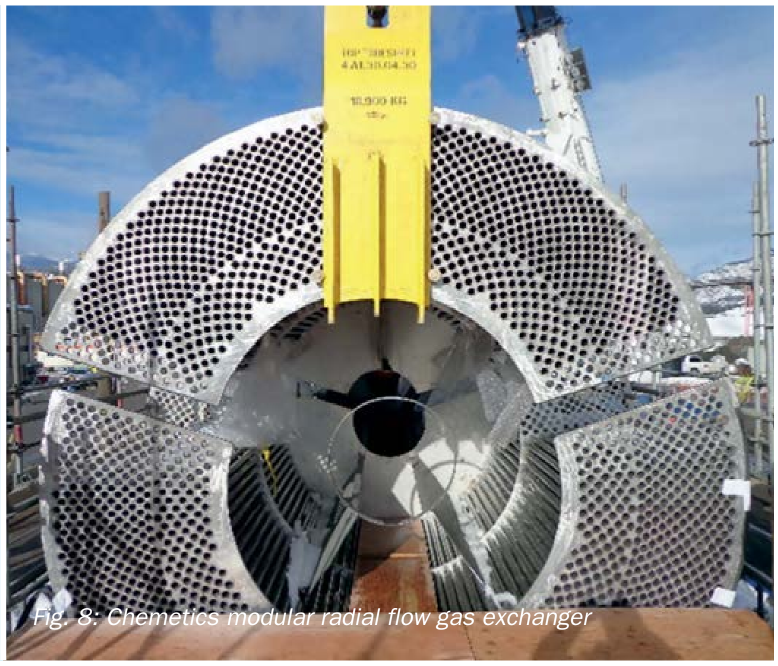


Fig. 8: Chemetics modular radial flow gas exchanger

impossibility of repairs. Equipment used in this service must be able to withstand corrosive effects of weak acid. Chemetics' innovation began with lining the carbon steel equipment with a fully bonded rubber lining and then providing thermal and mechanical protection by insulating with specific bricks. This prevented the fluoride attacks. FRP, often dual laminate, was introduced to prevent attacks from weak acid and wet SO_2 and high alloy plate exchangers were introduced to cool the weak acid. Further to this, Chemetics also developed two key pieces of equipment, the quench venturi, and the wet gas condenser. The quench venturi is used to adiabatically quench the hot 350 °C smelter off gas and needs to be able to withstand rigorous cycling and duty. The alloy wet gas condenser is used to replace the carbon steel equipment of the plant prior to the wet ESP utilising high alloy to withstand the harsh conditions, making retrofits easier and faster. Chemetics has brought value for over 35 years in the gas cleaning industry and continues to make breakthrough strides.

Chemetics fabrication shop

Chemetics is unique in the field of sulphuric acid design and supply as it is one of the only companies to own and operate its own in-house fabrication shop. The purchase of Fromson in 1981 was pivotal to the success and supply of Chemetics designed equipment worldwide as it allowed for strict quality control during the fabrication process to ensure the equipment was going to withstand the harsh conditions of production of sulphuric acid. Today, Chemetics can state that it has over 50 years of experience in fabricating high alloy equipment for acid, chemical, oil and gas industries, and in the last few years has also obtained nuclear certification for work on heat exchangers used in the nuclear industry. The new state-of-the-art facility opened in 2009 and expanded by more than 50% in 2024 boasts some of the most technical advanced manufacturing equipment, including plasma welding, a horizontal boring mill, laser cutting, a quick mill that can produce tube sheets of over 90" in one piece, etc. This experience allows Chemetics to control the equipment fabrication, and for equipment that is too large to ship from Canada, it has the necessary experience and knowhow to properly sub contract and manage fabricators worldwide.

PHOTOS: CHEMETICS

Fig. 9: Chemetics high alloy fabrication shop

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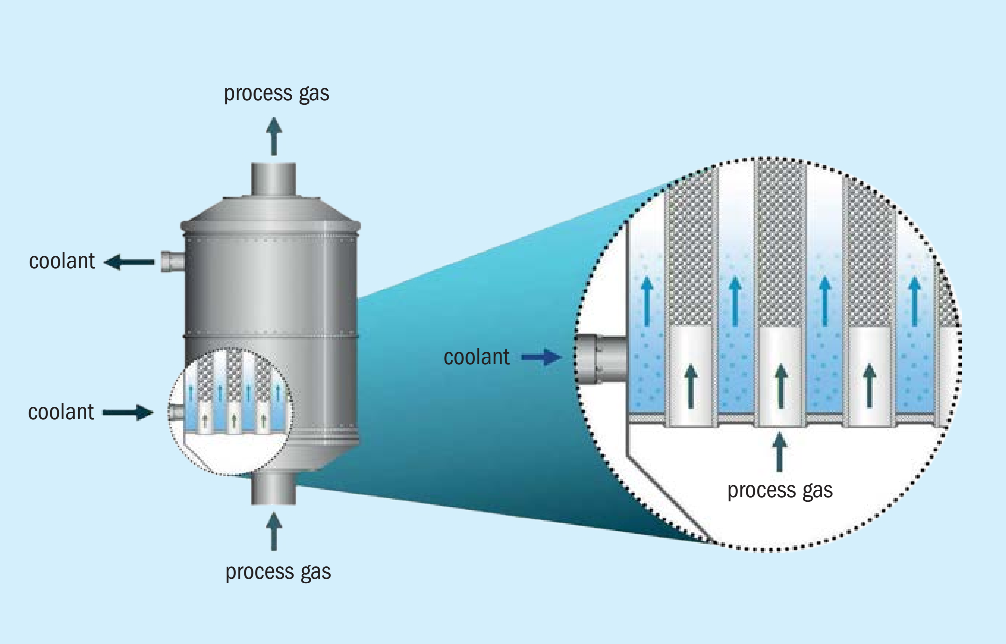
CORE™ converter

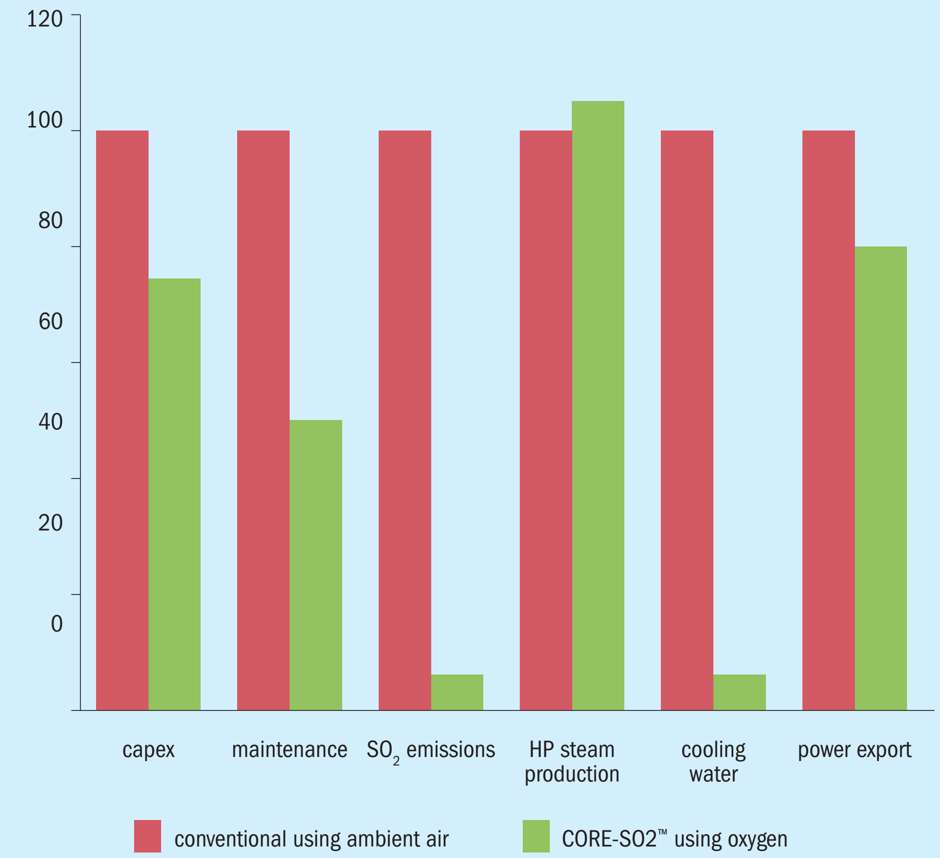
Invented in 2007, the iso-thermal one pass converter retains the ability to completely change the conversion process in the acid plant today. In the Cooled Oxidised Reactor (CORE™), a tubular oxidation reaction is used to convert SO_2 to SO_3 while avoiding the pitfalls of the adiabatic conversion process of hitting the equilibrium curve. This process removes the upper limit of SO_2 concentration typically seen and allows for conversion from concentrations higher than 30% directly to SO_3. The benefit is the reduction of the footprint of the plant by up to 60% and removal of plant equipment such as the final absorbing tower, gas exchangers, and economisers, reducing capex by 25%. Further reduction in size is possible when there is source of O_2 present within the plant, allowing the ability to utilise this high concentration conversion. Similarly, the CORE converter can be used for low SO_2 concentration plants when paired with an amine regeneration-based scrubber. The CORE converter is either air cooled, allowing for easy retrofit capabilities for enhanced expansion, or can be cooled with a molten salt when higher capacities are required. There are currently three of these plants in existence and this new conversion process is the latest innovation brought to the table by lowering capex investment and minimising emissions.

Fig. 10: **CORE™ converter**



Source: Chemetics

Fig. 11: **Adiabatic conversion vs CORE-SO2™ comparison**



Source: Chemetics

Chemetics approach

Over the course of 60 years Chemetics has provided projects in all different variations of supply from licensing packages all the way to turn key construction projects. In 2024, Chemetics has honed its scope of supply to provide the best value to its clients.

Chemetics' preferred scope of supply is a lump sum engineering procurement and service scope. This contractual model offers ease of mind for clients as it allows a technology company to focus on the core aspects of the plant and allows for other parties to perform the auxiliary non process and non-critical components such as the civil, electrical, structural, and construction. Chemetics offers full support during the construction phase to ensure that the Chemetics supplied units and other pieces of critical equipment are installed to applicable specifications. This entire scope of work is backed by a world class guarantee that has applicable scope drive remedies if required giving clients the reassurance that they are derisked when it comes to performance of the plant.

Conclusion

Chemetics has been and continues to be a key innovator and technology pioneer, consistently bringing new innovations, inventions, and improvements to the sulphuric acid industry and looks forward to servicing this community for another 60 years.

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