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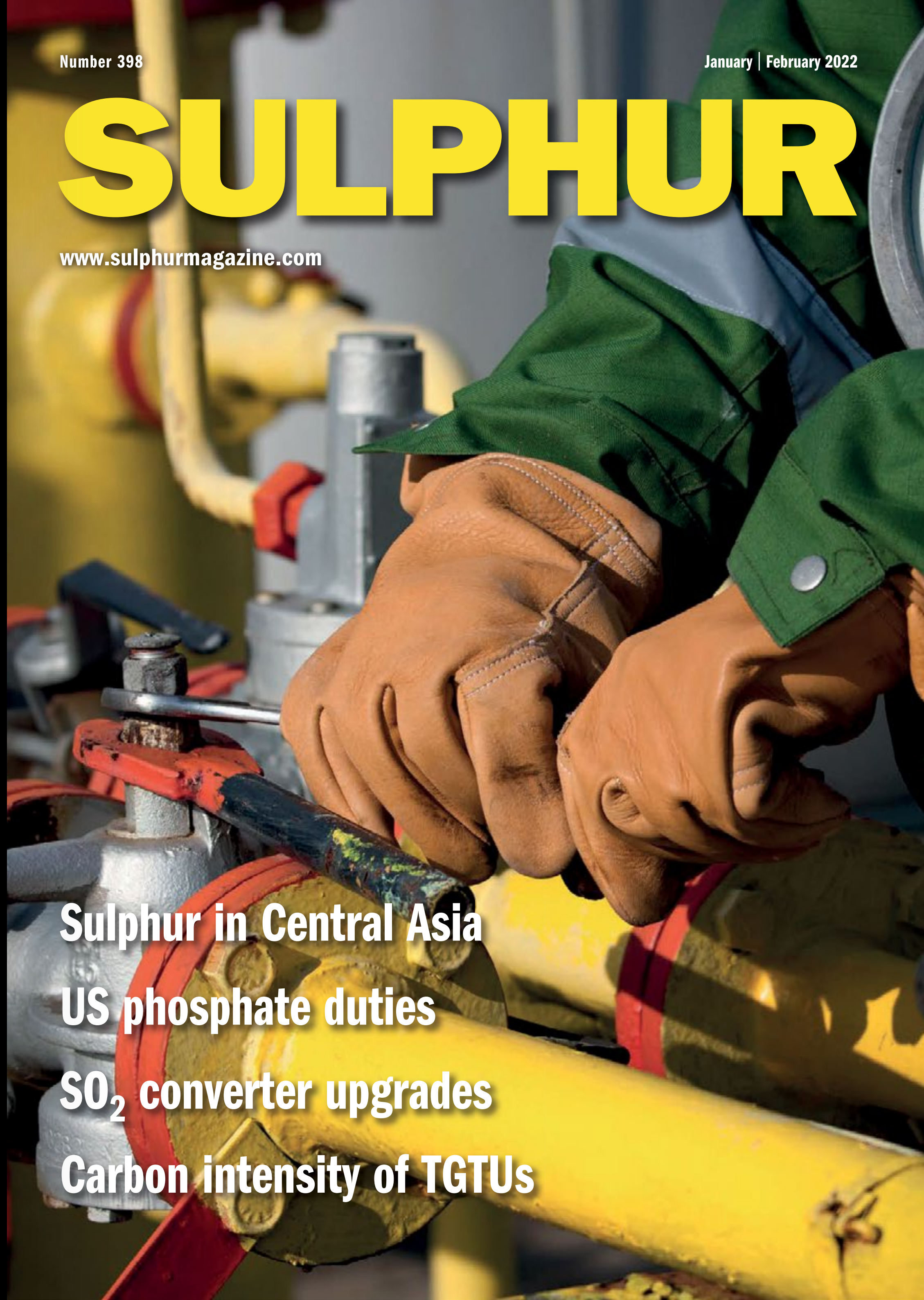




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JANUARY-FEBRUARY 2022

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## REGULARS





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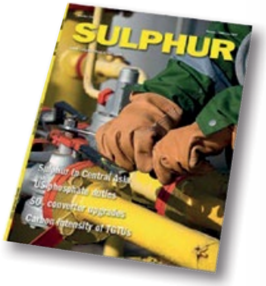
# A co-product again




It's a slightly dispiriting fact about the sulphur industry that most of its producers don't really want it. If you're a refiner or a sour gas producer, you mainly care about the diesel and gasoline or natural gas that you can process and sell, and the sulphur is just the inconvenient component that the law and your customers force you to remove. But at times when sulphur prices, as they have at the start of this January, reach levels as high as $300/t, then the industry standing joke is that sulphur suddenly stops being a by-product or waste product, and starts to become a 'co-product' instead.

The last time that sulphur prices reached this level was the 2008-09 price spike, a time when China's rapid industrialisation and consequent overheated commodity markets, coupled with overheated financial markets that eventually led to the great crash, drove sulphur spot rates to briefly reach unheard-of levels of $800/t. As former ASRL head and long-time industry commentator Jim Hyne said to me at the time: "*somebody* out there is making a lot of money", though it was often hard to get anyone to admit to who that might be. Even so, the current price spike is a remarkable turnaround considering that at the start of 2020, sulphur prices were down at $40/t f.o.b. Middle East.

> "There are signs that this particular sulphur price spike may be fairly short-lived."

This time of year is often a tighter time for sulphur markets, with availability from Central Asia constrained by weather. But on top of that, phosphate markets have been heading skywards as China cuts back on exports and the US imposes tariffs on product from Morocco and Russia. Russian fertilizer export quotas have merely exacerbated an already tight supply situation. Sulphuric acid markets are also tight, with European smelter acid production down due to maintenance turnarounds and nickel demand for battery production rising rapidly, boosting the need for sulphur-burnt acid.

There are signs that this particular sulphur price spike may be fairly short-lived; perhaps only a couple more months, and we needn't start melting down the Canadian stockpiles just yet. More sulphur is starting to flow from completed refinery projects in Kuwait and Saudi Arabia, and we should soon see, at long last, the impact of the much-delayed Barzan LNG project in Qatar. The gradual addition of 3 million t/a of sulphur capacity between the various projects should be enough to calm markets and bring prices back down by the end of the year. For now, though, the sulphur industry can enjoy another brief period of being a co-product again.

*Richard Hands, Editor*







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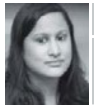
# Price Trends



**MARKET INSIGHT**

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

## SULPHUR

Global sulphur prices continued to firm through the fourth quarter of 2021 and into the new year, strengthened by firmer processed phosphate fertilizer market prices, heightened demand from major importers and supply constrainers in key regions. The Middle East benchmark breached the $300/t f.o.b. level at the end of December with further increases expected in the short term. The absence of China from the fertilizer export market led to tightness in the DAP market in the fourth quarter. Some DAP prices continued to firm in December, but signs that Chinese exports may resume is increasingly pointing to the potential for a downward correction. This is leading to a more bearish view for sulphur in 2022, although for the short term the trend remains firm, with limited signals of potential softening through January-March. Restricted availability from the Middle East coupled with seasonal delays from the FSU are factors underpinning the firmer trend.

ADNOC set its January official sulphur price for liftings for the Indian market at $300/t f.o.b. Ruwais, up by $35/t from the December prices of $265/t f.o.b. This followed a similar increase between November to December 2021. The Middle East – East Coast India freight rate for a 30,000-35,000t shipment was assessed at $32-33/t at the start of January, implying a delivered price in the low $330s/t c.fr. Kuwait's state-owned producer KPC also set its January sulphur lifting price at $300/t f.o.b., up by $33/t from the December price. Qatar's state-controlled Muntajat set its January Qatar sulphur price at $301/t f.o.b. Ras Laffan/Mesaieed, up by $46/t from the December QSP of $265/t f.o.b. These increases followed the spot tenders in the Middle East attracting bids up to the low/mid-$300s/t f.o.b. at the end of December. Meanwhile 1Q 2022 contracts from the Middle East are understood to have concluded at $275-285/t f.o.b., although final confirmations were awaited at the time of writing.

In Kuwait, the $14 billion Clean Fuels Project is complete with sulphur exports expected to increase during 2022 during ramp up. The long delayed 615,000 bbl/d Al-Zour refinery is expected to ramp up in the coming months. Combined the projects will lift sulphur capacity by 2.3 million t/a. Production is not expected to reach these levels in 2022, but Kuwait exports are forecast to rise to around 1.2 million t/a in 2022, exceeding the 1 million t/a mark for the first time. Other significant capacity additions are expected in Saudi Arabia and Qatar. Saudi Aramco's 400,000 bbl/d complex at Jazan was in final commissioning stages at the end of 2021. The Barzan project is expected to add 800,000 t/a sulphur capacity, with Qatar's exports increasing in 2022.

Facing uncertainty over long term demand for oil products, Gulf countries are unlikely to approve any further export-oriented refinery projects, bringing an end to more than a decade of rapid expansion. Forecasts by Argus see global oil products demand plateauing by 2030 as the shift towards low-carbon fuels gathers pace.

In China, spot prices were assessed by Argus at $160-345/t c.fr in mid-January, with the high end representing an increase of $40/t on a month earlier. China's restrictions on exports of fertilizers are in place until mid-2022 but small volumes of processed phosphates have moved from ports. Indications are that there will be a ramp up of Chinese fertilizer exports during the second quarter. Phosphates producers in Hubei province reduced production in mid-January because of maintenance, limited domestic demand and the upcoming lunar new year holidays, with run rates below 50% at plants. Average operating rates were around 55% in Guizhou and 60-65% in Yunnan. There is an expectation that DAP prices will start softening in February-March, after the lunar new year, but this will remain dependent on the export clearances situation. The potential downturn for phosphates implies a softer outlook for sulphur during 2022, with a price correction likely from the second quarter across key benchmarks.

Meanwhile, Morocco is expected to see increased sulphur demand in 2022 with continued ramp-up of phosphoric acid production. Argus forecasts sulphur imports to rise to 7.8 million t/a, with the potential for a more significant increase in the 2023-2024 period. Sulphur contracts for first quarter shipment concluded at the time of writing were reported in a range of $282-319/t c.fr, with some supply remaining under negotiation in mid-January. Spot prices were higher, at $290-323/t c.fr following a firmer sale for a small cargo. Offers for larger volumes from the Middle East and FSU were higher in the $340s/t c.fr and above in the spot market. Longer term Moroccan imports are forecast to rise to over 10 million t/a. The African region is the leading driver for the demand growth this year and in the medium term, forecast to close to 4 million t/a of sulphur consumption between 2021-2025.

## SULPHURIC ACID

Global sulphuric acid prices have firmed over the past month in most regions with the tight supply situation alongside healthy demand supporting the short-term outlook. Signs of softening emerged in Pacific markets. The gap has widened between export prices out of northeast Asia compared to the European region. Chinese export prices eased down to $130-140/t f.o.b., according to Argus assessments in mid-January, reflecting an average prices drop of $9/t on a month earlier. The trend has come on the back of the weaker domestic market following the implementation of fertilizer export restrictions in 4Q 2021. Domestic Chinese prices have also been dropping, adding some additional downward pressure to the export price in the short term. Prices from South Korea/Japan were at a similar level to China but have remained broadly stable between December and January, at an average level of $135/t f.o.b. There is potential for further softening in the short term in Asia but other markets are expected to hold firm on tight market balances.

Over in NW Europe, prices have increased by $9/t between December 2021 and January 2022 to an average mid-point assessed by Argus at $231/t in January. This marks a $199/t increase on prices compared with January 2021. The squeeze on supply has not abated in the new year, and this is likely to keep prices elevated through the first quarter of 2022. The focus at the start of the year was on quarterly and half-yearly negotiations for 2022. The region has been plagued with tightness on the back of smelter operating rates being cut, sulphur burner disruption and maintenance turnarounds. Contract prices for sulphur-based acid are expected to see significant increases. A range of euro 50-60/t is argued on the basis of the tight market balance but this remains to be seen.

On the supply front global metals group Nyrstar put its Auby zinc smelter in France on care and maintenance from the first week of January because of high power prices in the country. Operations at Nyrstar's two other European zinc smelters – Balen in Belgium and Budel in the Netherlands – are continuing at reduced capacity. Nyrstar had made the decision to curtail production by up to 50% back in October 2021 because high energy costs made it no longer economically feasible to operate at full capacity.

The upward pressure on sulphuric acid is likely to continue with Glencore's Portovesme and Boliden's Harjavalta not bringing product onto the regional markets. Further restrictions on European supply are on the horizon with maintenance planned at Polish-, Spanish-, German-, and Serbian-based acid producing facilities in the 2Q 2022.

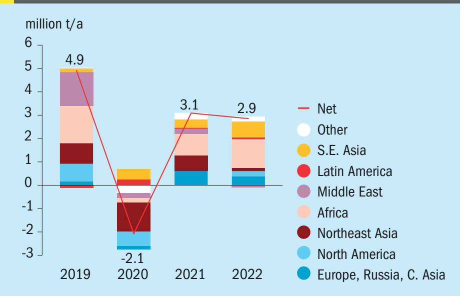
Metals futures markets have been mixed on macro signals and concern about the impact of the Covid-19 Omicron variant. However, nickel prices surged to a new highest level since 2011 on 14th January on a drawdown of stocks. Strong demand from the electric vehicle sector is contributing to the tightness in nickel availability, supporting acid demand in this sector.

Chilean acid markets closed in a range of $234-245/t c.fr Chile in mid-December. Those involved in the negotiations expressed how for 2022 it has taken a lot longer than in previous years. There has been a steep increase of course – the contract settled in a range of $56-62/t c.fr Chile in 2020. But in 2021 the spot price crept up to levels not seen in 12 years, and most expect it will remain elevated through 1H 2022. Chile's state-controlled miner Codelco has struck labour agreements with the union representing supervisors at its Salvador mine and the unions representing employees at its Chuquicamata mine. The SISPEL Supervisors Union, which represents supervisors at the Salvador mine, approved the new agreement with a vote of 94%. Codelco also reached agreements with the partners of the mining division at the Chuquicamata mine.

Buying activity picked up in South Asia in January but the India price softened down to $170-185/t c.fr in mid-January. The softening came amid reports that consumption has slowed as there was a lack of ammonia available for fertilizer producers and lower prices paid for prompt delivery.

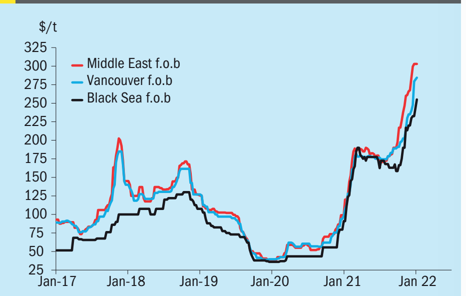
In North America, US acid imports rose to $150-258/t c.fr in mid-January as market participants considered the continued firmness in global sulphur and acid markets along with domestic logistical constraints. Labour shortages from both rail crews and hazmat certified trucking reduced reliability for timely deliveries.

Fig. 1: **Global sulphuric acid demand changes (y-on-y growth)**




*Source: Argus Sulphur Analytics*

Fig. 2: **Monthly Middle East sulphur producer prices**




*Source: Argus Sulphur*

# Price Indications

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

| Cash equivalent | July | August | September | October | November |
|---|---|---|---|---|---|
| **Sulphur, bulk ($/t)** | | | | | |
| Adnoc monthly contract | 175 | 175 | 180 | 194 | 230 |
| China c.fr spot | 256 | 215 | 230 | 302 | 325 |
| **Liquid sulphur ($/t)** | | | | | |
| Tampa f.o.b. contract | 195 | 195 | 195 | 183 | 183 |
| NW Europe c.fr | 228 | 228 | 228 | 228 | 228 |
| **Sulphuric acid ($/t)** | | | | | |
| US Gulf spot | 190 | 230 | 230 | 230 | 228 |

*Source: various*





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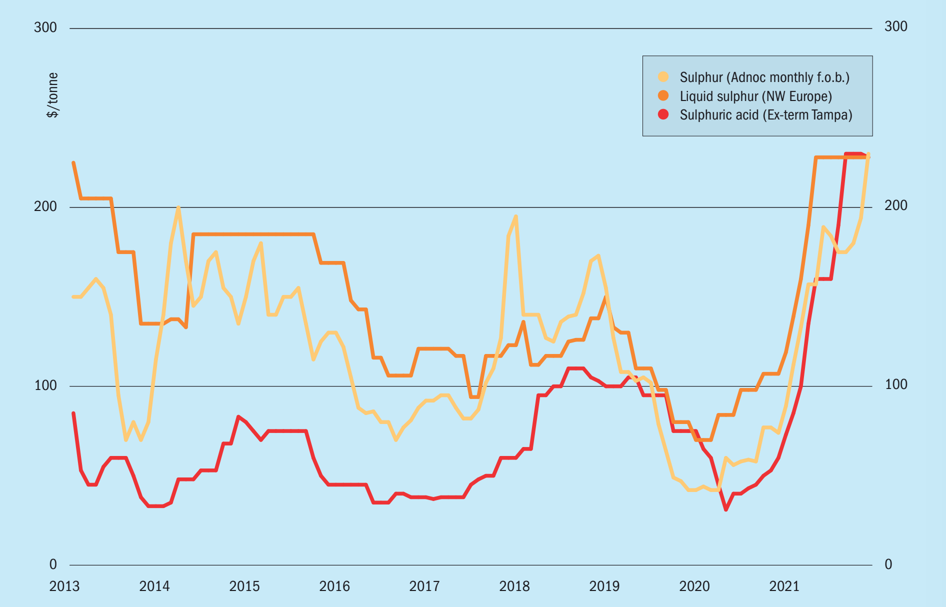
# Market Outlook

**Historical price trends** $/tonne




*Source: BCInsight*

## SULPHUR

- The processed phosphates market will be a major indicator for price direction for sulphur markets in 2022. A significant downward correction is expected in DAP prices with early signals prices could soften in the February-March period.
- The timing of increased processed phosphates exports from China will also be a key driver for the market in 2022. Small volumes have been cleared for export and expectations this will ramp up through the first half of the year, ahead of the end of the export restrictions.
- Metals markets are expected to add to global sulphur consumption in 2022. The nickel market is forecast to add around 900,000 t of sulphur this year, this is largely being driven by Indonesia with numerous projects already ramping up. This remains supportive for trade and pricing in the short term.
- **Outlook:** Global sulphur prices are likely to firm further in the early part of the quarter before plateauing in March and going into a potential downward correction from the second quarter. There is strong support for prices to run up through the remainder of January and in February because of supply disruption and strong demand. Later in the year, capacity is expected to increase in the Middle East and normalise at existing operations as fuel demand improves.

## SULPHURIC ACID

- Firmer sulphur prices continue to support the need for merchant acid but a price premium remains in most markets for acid. The ramp up of new sulphur capacity in 2022 could provide downward pressure for sulphuric acid as availability at sulphur burners is expected to improve.
- In December, the US Federal Open Market Committee decided to tighten its monetary policy with the phasing out of a stimulus programme by March – faster than previously planned. This signal that the US might raise interest rates more aggressively is dampening the sentiment in the copper and nickel futures markets, which came under pressure in late December from rising numbers of Covid-19 cases across Europe and the growing likelihood of further lockdown restrictions.
- Market participants are also weighing up the likely impact of planned production hikes for both copper and nickel. The global nickel market is expected to shift to a surplus in 2022, compared with the deficit in 2021. Indonesia will be the largest contributor to the production growth, especially across nickel sulphate feedstocks – nickel-cobalt mixed hydroxide precipitate (MHP) and nickel matte – and nickel pig iron (NPI). This will be a key driver for sulphur and sulphuric acid consumption growth.
- **Outlook:** Sulphuric acid prices are likely to firm further in Europe through the first quarter because of planned maintenances and ongoing curtailments at key smelters. Higher molten sulphur prices in the region will also support acid pricing. In Asia prices may soften further and the gap between European and Asian markets is set to continue in the near term as acid availability from China continues to improve through the year. ■





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# Sulphur Industry News

WORLD

## Oil demand recovering, except for aviation


PHOTO: PETERSCHREIBER.MEDIA / ISTOCKPHOTO.COM

Global demand for oil products has seen strong recovery in 2021, but depressed kerosene demand from the aviation sector continues to be a major barrier to full recovery, according to data and analytics company GlobalData. The company's analysis of oil product flows suggests that when kerosene is excluded, oil product demand in Q3 2021 had fully recovered compared to the same period in 2019. However, demand for kerosene, mostly used for jet fuel, has hovered at around two thirds of pre-Covid-19 levels throughout the year, and when that is taken into account, total oil product demand was 3% below pre-Covid levels for Q3 2021. Kerosene demand saw the greatest impact from Covid-19 due to restrictions on air travel. While the sector recovered, to an extent, in the second half of 2020, recovery stalled in 2021 due to new waves of infections and restrictions, with new restrictions linked to the Omicron variant likely to have hit demand again in Q4.

Will Scargill, Managing Energy Analyst at GlobalData, commented: "China has been the driver for the global demand recovery, led by gasoline in the transport sector and continued growth in naphtha and LPG as the country expands its petrochemicals sector. Other major economies are still yet to see demand fully recover to pre-Covid-19 levels, but the strength of China's growth plugs the gap. Still, the depressed aviation sector means a significant global demand shortfall, leaving open the prospect that we may have already seen peak oil demand – given the acceleration of energy transition to renewables."

> **"In developed economies road transport activity has not fully recovered and the important European market is increasingly turning away from Diesel vehicles due to air quality concerns.**

Diesel and Kerosene are both yet to see demand fully recover. China has not provided the same boost for diesel as other products, as the country's use was already in decline pre-COVID-19 and global demand in Q3 2021 remained around 4% below 2019 levels. Chinese diesel demand appears to have peaked in 2015 amid moderating economic growth and a switch to cleaner fuels.

Meanwhile, in developed economies road transport activity has not fully recovered and the important European market is increasingly turning away from Diesel vehicles due to air quality concerns.

Nick Wyatt, Head of Research for Travel & Tourism at GlobalData added: "Continued restrictions will have a negative impact on demand for air travel. The conundrum facing airlines is deciding how much capacity to keep online in the short term. Low load factors impact profitability and many airlines are not in a position to absorb loss-making flights. Consequently, there is a risk that they will err on the side of caution and ground some of their fleets to reduce running costs if they see demand softening."

CHINA

## Sinopec starts up new alkylation unit

Ellesent Clean Technologies, the new owner of the former DuPont Clean Technologies suite, says that the *STRATCO*® alkylation unit at the Fujian Refining and Petrochemical Co., Ltd refinery in Quanzhou has successfully started up and completed performance tests, certifying that the unit is meeting performance guarantees. The alkylation unit is designed to produce 7,700 bbl/d (300,000 t/a) of alkylate from a mixed butylene fluid catalytic cracker feedstock. *STRATCO* is a sulphuric acid-catalysed process that converts low-value, light olefins (propylene, butylene and amylene) into high-value, branched components called alkylate.

This start-up is the seventh *STRATCO* alkylation unit within Sinopec and allows compliance with the China VI standard which limits sulphur content in gasoline to a maximum of 10 ppm by generating low-sulphur, high-octane, low-RVP alkylate. As the world's largest vehicle market in the world, China is committed to improving air quality in the country by introducing legislation, such as the China VI fuel standards, to reduce automobile-generated pollution. Alkylate produced by Sinopec will meet both the current China VIA fuel standard and the VIB standard expected to come into force in 2023, which further reduce the levels of benzene, aromatics and olefins in the gasoline pool. As a paraffinic hydrocarbon, alkylate plays a key role in improving air quality and public health.

"Over the last several years, we have been able to work with multiple Sinopec refineries, building an energetic relationship and providing a reliable technology solution at each site. The consistency of our technology provides Sinopec the ability to deliver high quality alkylate to the gasoline pool, decreasing the environmental impact of its fuels. It has been a pleasure to work regularly with the Sinopec organisation, a rapport that will continue throughout the lives of these seven units," said Kevin Bockwinkel, global business manager, *STRATCO* Alkylation Technology.






PHOTO: PDO

*The Yibal Khuff development.*

OMAN

## PDO inaugurates Yibal Khuff project

Petroleum Development Oman (PDO), the majority state owned oil and gas producer, has officially inaugurated its Yibal Khuff project (YKP), an integrated $2.6 billion oil and sour gas facility located approximately 350 km south west of Muscat. Production actually began in September 2021 from four sour oil wells drilled as part of the project. The oil is pumped to the YKP Central Processing Facility. When fully operational, the project will be delivering 5 million scf/d of natural gas and around 20,000 bbl/d of crude to meet the Sultanate's growing medium and long- term oil and gas demands, as well as reducing PDO's net non-associated gas import. UK-based Petrofac was selected in 2015 to oversee the development of the giant project as part of an engineering, procurement and construction management contract.

According to PDO, YKP has achieved several significant firsts, including the tallest column ever fabricated in Oman. This acid gas recovery unit absorber stands 48 metres high, four metres in diameter, and weighs 291 tonnes. The project has also included one of PDO's first steam turbine generators, taking heat fro m some of the facilities' processes and using it to generate steam. The plant will be able to generate 13MW of electrical power, supplementing the 45MW of the Yibal Khuff power plant.

Processing of sour gas from the project is expected to produce 235 t/d of elemental sulphur at capacity.

VENEZUELA

## Belated gains in oil sands production but no overall increase in output

Venezuelan state-owned PDVSA and its foreign joint venture partners recorded average crude oil production of 560,000 bbl/d in 2021, according to an internal report. The figure is below 2020's 570,000 bbl/d and well down on 2019's figure of 1.0 million bbl/d. Around 60% of the oil production in 2021 came from joint ventures with foreign firms, mainly in the Orinoco oil sands belt, with the remaining 40% coming from PDVSA's own production. Both figures were well down on the targeted figure, which had planned for production to rise back to 1 million bbl/d. According to the report, factors which had caused the lower output included recurring power failures, excess water and sulphur in the crude, deferred production due to deviations in the contractors' work plan and delays in service contracts, and the acquisition of materials and equipment.

Four joint ventures in the Orinoco Belt increased production, starting in September when condensate imported from Iran became available for use as a diluent for the extra heavy crude: Petropiar produced 47,000 bbl/d on average for the year, Sinovensa 60,000 bbl/d, Petromonagas 64,000 bbl/d, and Petroindependencia 15,000 bbl/d. However, the figure for December showed total Orinoco output had risen to 550,000 bbl/d, and overall production 830,000 bbl/d, with crude production at the Zulia-Trujillo fields rising to 150,000 bbl/d, 40,000 up on the previous month. The 8.5% API extra-heavy crude extracted from the giant Orinoco Belt oil field can only be marketed if it undergoes an upgrading process by blending it with light crude, condensates or naphtha.

KAZAKHSTAN

## Feasibility study on sour gas monetisation

North Caspian Operating Company (NCOC), operator of the Kashagan field, is partnering state run gas pipeline operator Kaztransgaz to researching options for transporting and processing of sour gas produced from the Caspian Sea. The project partners will consider proposed solutions following


PHOTO: PETROFAC

*Onshore facilities at Kashagan.*





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completion of front-end engineering design studies on planned offshore and onshore gas pipelines and an onshore gas processing plant. These studies are expected to become available between 2022 and 2023 and will enable the partners to reach a final investment decision on the first phase of a plan to expand production, according to Kaztransgaz.

The project calls for development wells to be drill into an untapped section of the Kashagan reservoir, with production from expected to begin in 2027 and add up to 50,000 bbl/d of oil production. NCOC will also produce an additional 4.2 million scf/d of sour gas. Most of that gas will be sent to shore via a proposed pipeline link and on to a processing plant with a capacity of 2 bcm/year of gas. It would be the second onshore facility to remove off-spec hydrocarbons, sulphur and hydrogen sulphide from Kashagan's gas mixture before volumes can be sent into the main national pipeline network. Earlier this year, Kazakh contractor GPC Investment started construction of the first facility. The $1.1 billion plant aims to take 1.1 bcm of sour gas annually from Kashagan and supply about 815 million cubic metres per annum of dried gas to the trunkline network.

## UNITED STATES

### Refinery margins aided by cheap gas

US refining margins have been boosted over the past couple of months by the widening split between relatively low prices for sour crude compared to lower sulphur feeds, and the relatively cheap price of natural gas in US markets compared to record high prices in Europe and Asia. Inexpensive gas makes the cost of producing hydrogen to process sour crude relatively cheap, allowing US refiners to take advantage of low sour crude prices; Mexican sour Maya crude, for example, was trading nearly $10/bbl below US Light Louisiana Sweet during December 2021. Oil industry consultants OILA say that US Gulf Coast refining margins are at their highest levels for four years. Refinery sales have been boosted by increased demand for gasoline and diesel as the country recovers from the Covid pandemic.

Increased processing of sour crudes rather than the sweet crudes that had predominated as feedstocks earlier in 2021 should see sulphur production at refineries rise again. In September production was around 50,000 tonnes per month down on the 2020 figure. Even so, Argus says that it expects US domestic and global sulphur demand to outstrip spot sulphur availability and drive price rises further in early 2022. Shortages have been exacerbated by flood damage to rail lines near Vancouver and anticipated Chinese demand ahead of the Lunar new year holiday and Beijing Winter Olympics in February.

## UNITED ARAB EMIRATES

### Technip awarded Ghasha update contract

Technip Energies has been awarded a contract by the Abu Dhabi National Oil Company (ADNOC) to update the front-end engineering design (FEED) for the Ghasha sour gas mega-project, including the integration of carbon capture into the development. Technip said in a press statement that the overall objective of the updated FEED will be to further optimise the project costs as well as accelerate the integration of carbon capture, adding that the $CO_2$ capture, dehydration and export will reinforce ADNOC's decarbonisation and sustainability commitments.

The Ghasha project is a joint venture between ADNOC (50%) and Eni (25%), Wintershall (10%), OMV (5%), and Lukoil (5%). It aims to develop untapped oil and gas reserves from the Ghasha Concession fields; the world's largest offshore sour gas development. The Concession area is expected to produce over 1.5 billion scf/d of natural gas, as well as condensate and oil. The start of production from the concession is expected in 2025, ramping up to full production by the end of the decade.

Marco Villa, Chief Operating Officer of Technip Energies, said: "We are very proud to have been awarded this FEED which will be one of the largest ultra-sour gas project Technip Energies has worked on. This award is recognition of the strong competencies in gas processing as well as the relationship and trust that ADNOC has with Technip Energies for such strategic project. As part of our energy transition journey, we will contribute to a robust design of carbon capture and transportation for enhanced oil recovery, a critical element of this project. For the past four decades, we have been committed to ADNOC through added value services and continued our commitment to expand local execution capabilities and enhance In-Country Value."

## MEXICO

### Sour gas sweetening plant for Ixachi

Malaysian oil and gas services firm Coastal Contracts has agreed with Mexican exploration and production company PEP, a subsidiary of national oil company Pemex, to build an onshore gas conditioning plant at the Ixachi field in Mexico. The $1 billion project will be undertaken with Coastal Contracts' long-term Mexican business partner, Nuvoil, through their JV Coastoil Dynamic. The joint venture began operations at its first gas conditioning facility, the Perdiz plan, in July 2021. Perdiz is also attached to the Ixachi field in Tierra Blanca, Veracruz state. Coastal Contracts said it expects the second plant, Papan, to be online by 3Q 2023, with the scope of work comprised of engineering, procurement, construction, operation and maintenance of the gas conditioning plant and its related infrastructure for the first 10 years of operation. Both gas sweetening plants have nameplate capacity to process 180 million scf/d of sour natural gas and reduce hydrogen sulphide and carbon dioxide content from 1,100 ppm to 4.25 ppm.

## SAUDI ARABIA

### Aramco to boost refinery sulphur recovery rates

Saudi Aramco has asked contractors who are part of its 'long-term agreement' (LTA) pool to submit final bids to maximise sulphur dioxide recovery rates from its Riyadh and Ras Tanura refinery projects. According to Middle East Economic Digest, the combined value of the engineering, procurement and construction (EPC) works on the two projects could be worth up to $500 million. Aramco first issued tenders for the projects in January 2021, but the bid deadline was extended first to September, November and then December 2021. The scope of work on both projects is to modify existing sulphur recovery units as well as install tail gas treatment units (TGTUs), to increase sulphur dioxide recovery at the two refineries from 96-97% to 99.95%. Front-end engineering and design work on both the Riyadh and Ras Tanura refinery projects has been done by Jacobs-ZATE, with Fluor providing licensed technologies for the project.



# Sulphuric Acid News

## UNITED STATES


*A MECS sulphuric acid plant.*

### DuPont sells Clean Technologies business

DuPont has agreed to sell its Clean Technologies business for $510 million to an international private equity consortium, comprising BroadPeak Global, Asia Green Fund and The Saudi Arabian Industrial Investments Company (Dussur). The new, independent company has been named Elessent Clean Technologies and will be a global leader in process technologies to drive sustainability and carbon neutrality in the metal, fertilizer, chemical and oil refining industries. Elessent retains exclusive rights to the technologies, expertise, products, and services including: *MECS*® sulphuric acid and environmental technologies, *BELCO*® scrubbing technologies, *STRATCO*® alkylation technology and *IsoTherming*® hydroprocessing technology. Derived from the words "element" and during the first half of 2022. The parties have decided not to disclose the value of the transaction. The business sold to Mimir includes the brands Lindemann and Texas Shredder. The business will change name in conjunction with the divestment and operate globally under the Lindemann brand, with headquarters in Düsseldorf, Germany. Its current approximately 160 employees will transfer to the new company in connection with the transaction. The net sales of the business totalled €77 million in 2020.

"We are delighted that going forward, the Metal Recycling business will continue to implement its strategy together with the new owner Mimir. As an established standalone company, its full focus will be on the metal recycling markets and customers," says Piia Karhu, Senior Vice President, Business Development and Metal Recycling business line at Metso Outotec.

## AUSTRALIA

### Feasibility study for large scale sulphuric acid plant

SNC-Lavalin says that it has been commissioned to undertake a definitive feasibility study for Verdant Minerals Pty Ltd on their







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PHOTO: BOLIDEN

*The Boliden Odda zinc smelter, Norway.*

its major new mine and processing development, ensuring the long-term sustainability of its operations," said Patrick Sikka, Vice-President, North America, Mining & Metallurgy at SNC-Lavalin.

## NORWAY

### Metso Outotec to license acid plant for zinc smelter expansion

Metso Outotec has been awarded a €150 million contract for the delivery of key technology to the Boliden Odda zinc smelter expansion in western Norway. Boliden Odda is planning to increase its annual production capacity of zinc from 200,000 t/a to 350,000 t/a. Several by-products will also be produced. The project is called Green Zinc Odda, and its energy consumption is based on fossil-free energy. Metso Outotec scope of delivery includes roasting and off-gas cleaning solutions and a sulphuric acid plant. Metso Outotec will also supply hydrometallurgical equipment and technology for calcine leaching, solid liquid separation, solution purification, as well as process and plant engineering and site services. Metso Outotec deliveries will take place in 2022-2024. The company says that its zinc processing technologies consist of several proprietary 'Planet Positive' solutions which enable efficient zinc and by-product recovery from a wide range of primary zinc raw material. In the roasting process, even electrical power is produced as a by-product.

"We are very happy for being trusted with this order. The Green Zinc Odda project paves way for more sustainable zinc production and is yet another important milestone in the many years of collaboration between Boliden and Metso Outotec," says Jari Ålgars, President, Metals business area at Metso Outotec.

## INDONESIA

### First production from HPAL project

China's Zhejiang Huayou Cobalt says it has achieved its first trial output of nickel and cobalt mixed hydroxide precipitate from its PT Huayue project on Sulawesi. Zhejiang Huayou is operating the project in partnership with Tsingshan Holding Group and China Molybdenum Co. PT Huayue is designed to produce 60,000 t/a of nickel and 7,800 t/a of cobalt per year using high-pressure acid leach (HPAL) technology. Huayou also has a 20% stake in a larger HPAL project in Indonesia, while another Indonesian HPAL scheme, led by GEM, is targeting start-up in 2022.

### Contracts awarded for copper smelter

After the October 2021 groundbreaking ceremony for PT Freeport Indonesia's new copper smelter at the Special Economic Zone Java in Gresik, a second new copper smelter project is also progressing as PT Amman Mineral Industri (AMIN) has recently finally signed contracts with two major contractors to build AMMAN's new 900,000 t/a copper smelter and precious metal refinery in West Sumbawa, Tenggara Province. It means that Indonesia will soon have three copper smelters – PT Smelting Gresik, which has been operating as the single domestic smelter since 1996, plus the new Freeport and AMMAN smelters.

The contracts were signed between AMIN and China Non-Ferrous Metal Industry's Foreign Engineering and Construction Company (NFC) as well as PT Pengembangan Industri Logam in December 2021. NFC will be the main contractor supplying materials and equipment for the copper smelter. The technology and patented equipment for the project will be procured from prominent original equipment manufacturers around the globe, including MECS for the gas cleaning and sulphuric acid plants.

NFC's President Qin Junman, said: "As one of the top international contractors, NFC has successfully completed numerous projects, including copper smelters with the latest technology. We are confident that we will build this project into a world-class one with the help and support from the government, AMMAN, and our partners. During the Covid-19 pandemic, the project will be very challenging. However, we want to ensure that all necessary resources are available for smooth, successful, and on-schedule project implementation."

### Tsingshan starts producing nickel matte

China's Tsingshan Holding Group says it has officially started producing nickel matte in Indonesia for electric vehicles. The company is making matte from stainless steel raw material nickel pig iron (NPI) and nickel sulphate, an alternative route to battery-grade nickel to the high-pressure acid leach (HPAL) process which is also aiming to be used by Tsingshan and several other companies in Indonesia. Tsingshan said in March 2021 it planned to sell 60,000 tonnes of matte to Huayou and another 40,000 tonnes to CNGR within a year of first production.





## RUSSIA

### Nornickel expects Sulphur Programme completion in September

Nornickel says that it has made significant progress with delivery of large-scale equipment as part of its Sulphur Programme in Norilsk. The programme includes an investment of over $4 billion to capture emissions at the Nadezhda and Copper plants with intermediate production of sulphuric acid with a high rate (>99%) of sulphur dioxide recovery. As of the beginning of December 2021, more than 700 tonnes out of the planned 7,000 tonnes of various equipment items had already been installed at the site. The assembly of ball mills at the calcium hydroxide production section that will make the powder for this important solution is currently underway. The sulphuric acid generated as part of Nornickel's metallurgical operations will be recovered and neutralised using the calcium hydroxide solution ('milk of lime') to produce gypsum.

Contractor Velesstroy has already installed the largest section of the ball mills; a drum weighing 28 tonnes. Heat exchangers for the sulphuric acid production section – the biggest project units, weighing over 200 tonnes each – are expected to arrive at Dudinka Port soon. In the near future, the company says that it plans to complete thermal envelopes at the slaked lime and sulphuric acid production sections. Plans for the next three months include the construction of building frames and thermal envelopes at three other key facilities of the Nadezhda Metallurgical Plant.

"The list of equipment is extensive and includes chemical, mechanical and process units. They come together with a wide range of auxiliary systems, from ventilation to water supply and water treatment. This will be the most advanced facility to be launched within the Sulphur Programme. We are planning to complete the full process cycle, including start-up operations, in September 2022," said Pavel Zhigulin, Senior Manager of the Sulphur Programme Project Management Office at Nadezhda Metallurgical Plant.

## SOUTH AFRICA

### Start-up for Elandsfontein phosphate plant

Kropz says this it has achieved a major milestone with the first introduction of phosphate ore to the beneficiation plant at the company's Elandsfontein mine in South Africa. Team is now ensuring that alle front end circuits are balanced and running stably. The flotation circuits will then be commissioned and the reagents added in due course for the production of the first concentrate. Commissioning activities will transition into full scale ramp-up of the mining and beneficiation plant over the coming six months. Mining activities commenced in October 2021, and significant volumes of ore are available to support the commissioning ramp-up.

CEO Mark Summers said: "The introduction of ore to the processing plant reflects the successful culmination of the construction phase and signals the commencement of the next chapter in the Company's development. I would like to express my gratitude and appreciation for the tireless efforts of all of those involved in reaching this milestone safely and on time, despite the many challenges that the past two years have presented."

Transnet has provided the Company with a draft port access agreement to support the long-term export of Elandsfontein's phosphate rock through the port of Saldanha. First phosphate rock exports from Elandsfontein are expected in Q1 2022.

## PHILIPPINES

### Sumitomo increases share in Coral Bay Nickel Corporation

Sumitomo Metal Mining Co., Ltd. (SMM) says that it has reached an agreement with Mitsui and Sojitz for the purchase of shares in the Coral Bay Nickel Corporation. Sumitomo is buying Sojitz 18% shareholding in the company, as well as the 18% owned by Mitsui subsidiary Mitsui & Co. Mineral Resources Development (Asia) Corp. (MMRDA), at a total cost of $164 million. The purchase will take SMM's share in the company from 54% to 90%. The remaining 10% of shares are held by the Nickel Asia Corporation. Based on the assumption that all necessary permits and approvals are acquired, the sales of the shares are planned to be completed by the end of January 2022.

Coral Bay is a major nickel high pressure acid leach (HPAL) plant, and began commercial operations in 2005.

## CHILE

### Project for copper tailings treatment

Researchers at Chile's Pontifical Catholic University are working on a project called Tailings to Construction Materials (T2CM), which aims to transform copper tailings into high-quality polymers and cements. The project is part of BHP's Tailings Challenge and is backed by DITUC, a research centre; Melon, a leading cement company; Eral, an engineering firm; the Paris Geopolymer Institute; and Noracid, a manufacturer of sulphuric acid. T2CM's goal is to transform all tailings produced at a given operation into usable components for buildings by using cleaning/extractive processes to recover copper and molybdenum as well as sulfuric acid. As well as reducing the accumulation of tailings, the process would also drastically reduce the almost one tonne of $CO_2$ that is released into the atmosphere per tonne of cement produced using conventional techniques. It involves transporting fresh tailings to a nearby or on-site treatment facility, fine grinding and particle size classification of the tailings for surface activation, as well as rougher sulphide flotation to obtain a desulphurised material and a sulphur polymetallic concentrate. The sulphur-enriched material is then separated into copper sulphide and a pyrite fraction by flotation, and the pyrite-enriched concentrate goes to a roasting step for sulphur removal and sulphuric acid production. Finally, the iron oxide desulphurised material is used to develop construction materials.

## TUNISIA

### Tunisia records major phosphate export boost

Tunisia's National Institute of Statistics says that the country's monthly trade deficit narrowed to $467 million in November 2021. Partly this was explained by a fall in imports of oil, gas and raw materials, in spite of a 20% increase in capital goods imports. But it was helped by a major increase in exports from the mining, phosphate and derivatives sector of 51% for the month. In particular, exports of phosphoric acid to Algeria were up by 90%. ■







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Nutrien Ltd has announced that **Mayo Schmidt** has left his position as president and CEO of Nutrien and has resigned from the Board. **Ken Seitz**, Executive Vice President and CEO of Potash, has been named the company's interim CEO. Seitz brings extensive global leadership experience in the agriculture and mining sectors and is well-positioned to progress the company's stated strategy and lead the integrated business during the transition.

Russ Girling, Chair of the Nutrien Board of Directors, said: "Nutrien has a talented and deep executive team, and we are confident that Ken Seitz and this team will continue to build on the organisation's record financial and operating performance. The Nutrien Board of Directors will work with an executive search firm to begin a global search to select a long-term leader that will take the company into its next phase, which will consider internal and external candidates.".

Mr. Seitz said, "I look forward to working with the executive leadership team, our tremendous employees and the Board of Directors to execute on our plan, continue this exciting progression across our business to serve our stakeholders, and deliver on our commitment to advance sustainable solutions to feed a growing world."

Seitz joined Nutrien as Executive Vice President and CEO of Potash in 2019. He has 25 years of global management experience working across more than 60 countries, and was a former president and CEO of Canpotex, one of the world's largest suppliers of Potash.

Sherritt International has announced the planned retirement of Chief Operating Officer **Steve Wood**, effective from April 30th, 2022. Mr. Wood has worked in the mining industry for more than 40 years, including the past seven as Sherritt's COO. As a result of Wood's planned retirement, the company gas made a number of promotions to its leadership naming: **Dan Rusnell** as Senior Vice President, Metals; **Elvin Saruk** as Head of Growth Projects in addition to his accountabilities as Senior Vice President for Oil & Gas and Power; and **Greg Honig** as responsible for Marketing and the Technologies group in addition to his accountabilities as Chief Commercial Officer.

"Steve has provided invaluable guidance on Sherritt's operations over the years, and I am grateful for his support and the many contributions he has made as a key member of the senior leadership team," said Leon Binedell, President and CEO of Sherritt International. "As a driving force behind our purpose and promises, Steve's legacy at Sherritt will be remembered for his commitment to safety, sustainability, operational excellence, and growth. On behalf of everyone at Sherritt, I would like to extend Steve best wishes for his upcoming retirement and look forward to his active role in the pending transition period."

"Dan, Elvin, and Greg have the right skills, experience, and expertise in their respective roles to drive our growth strategy forward," said Mr. Binedell. "The promotions, which are effective from January 1st, 2022 and will report to me directly, will help us to better align the organization to our growth initiatives while maintaining strong relationships with our key stakeholders, including our Cuban partners, customers around the world, and the local communities in which we operate."

The Copper Development Association, Inc. (CDA) has announced the appointment of **Andrew G. Kireta, Jr**. as the association's next President & CEO, effective from January 1st, 2022. He succeeds **Thomas S. Passek**, who will retire at the end of 2021 after nearly seven years with the organisation.

"The Copper Development Association's Board of Directors is thankful for the nearly seven years of thoughtfulness, balance, and skill with which Thomas led the organisation. He has encouraged and stimulated member engagement, navigated the organisation through a period of significant change and created a culture of staff support and growth. He has left his mark and we wish him the best in his future endeavours," said Devin Denner, Chairman of CDA's Board of Directors and President of Wieland Chase. "We're confident that Andy will continue to lead CDA and its member companies forward to a position of strength and resilience, necessary for bringing the value of copper and its alloys to society."

Kireta brings nearly 30 years of copper industry experience to the role. He has been with the CDA since 1992, having previously served multiple roles in market development, strategy, and organisational management in regional and national roles, most recently as vice president of market development across all copper and copper alloy product and market areas. In addition, Kireta has served in various team roles with the International Copper Association (ICA), including time as the leader of the global strategy team, and as a Board member with various roles on the executive committee of ASTM International including a term as the 2020 Chair of the Board.

## Calendar 2022

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

### JANUARY

**23-25**
Sour Oil & Gas Advanced Technology (SOGAT), ABU DHABI, UAE – **POSTPONED**
Contact: Nick Coles, Director – Conferences
DOME Exhibitions,
P.O. Box 52641, Abu Dhabi, UAE
Tel: +971 2 674 4040
Email: nick@domeexhibitions.com

### FEBRUARY

**1-4**
SulGas Conference 2022 – **VIRTUAL EVENT**
Contact: Conference Communications Office
Tel: +91 73308 75310
Email: admin@sulgasconference.com

**21-24**
Laurance Reid Annual Gas Conditioning Conference, NORMAN, Oklahoma, USA
Contact: Lily Martinez, Program Director
Tel: +1 405 325 4414
Email: lmartinez@ou.edu

### MARCH

**7-9**
CRU Phosphates 2022 Conference, TAMPA, Florida, USA
Contact: CRU Events, Chancery House, 53-64 Chancery Lane, London WC2A 1QS, UK
Tel: +44 (0)20 7903 2444
Fax: +44 (0)20 7903 2172
Email: conferences@crugroup.com

### MAY

**9-11**
TSI Sulphur World Symposium 2022, TAMPA, Florida, USA
Contact: Sarah Amirie, The Sulphur Institute
Tel: +1 202 296 2971
Email: SAmirie@sulphurinstitute.org

**17-18**
The 8th Sulphur and Sulphuric Acid Conference 2022, CAPE TOWN, South Africa
Contact: Camielah Jardine, SAIMM,
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Marshalltown 2107, South Africa
Tel: +27 (11) 834-1273/7
Email: camielah@saimm.co.za





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# Sulphur in Central Asia

PHOTO: GAZPROM

*Above: Gazprom's Orenburg gas processing plant.*

Sulphur processing from sour gas fields dominates regional production, but the geographical remoteness of the area from end use markets and restrictions on sulphur storage means that producers often opt to reinject acid gas into oil and gas wells.

Central Asia – the collection of post-Soviet states clustered around the Caspian Sea, as well as nearby or associated facilities in Russia and Iran, is responsible for around 15% of the world's elemental sulphur production. It is based around large reserves of oil, gas and condensates, much of sour or highly sour. Processing of sour gas in the region has a long history – last year the Orenburg gas processing plant in Russia celebrated its 55th year of operation. But continued development of oil and gas fields continues to generate additional volumes of sulphur.

At the same time, however, domestic consumption of sulphur in the region is relatively low, aside from phosphate production elsewhere in Russia, and Kazakhstan's burgeoning uranium mining industry. That, coupled with its location in the centre of the Asian continent, with no nearby ports for long distance export, makes sulphur export logistics challenging, even before the region's notoriously harsh winters are taken into account.

## Russia

Russia has long been the major regional producer of sulphur, from oil, gas and condensate fields in the Orenburg and Astrakhan regions just north of the Caspian Sea. Both are operated by subsidiaries of Russia's state-run gas giant Gazprom; Gazprom dobycha Orenburg and Gazprom dobycha Astrakhan, respectively.

Orenburg is a huge gas processing complex, able to process 37.5 bcm of gas in three trains, removing hydrogen sulphide and carbon dioxide, and recovering large quantities of helium. Gas from the local Orenburg fields averages around 3% $H_2S$ content. However, Orenburg was also set up to receive gas from the Karachaganak field in Kazakhstan, where $H_2S$ content is considerably higher – around 13%, and the plant required modification to handle this when the feed from Karachaganak was first tied in. The facilities were developed together during the Soviet era and still work closely. Orenburg also has a refinery to process oil from the local fields. produces major volumes of oil, some of which is processed at the local Orenburg refinery.

At Astrakhan, meanwhile, gas is taken from the Krasnoyarsky gas and condensate field, where reserves are put at 90 bcm of gas and 260 million tonnes of oil. Annual production is around 11 bcm of gas and 4 million t/a of hydrocarbon liquids. Krasnoyarsky gas is very sour, with a sulphur content of up to 31% hydrogen sulphide, which means that although Orenburg actually processes more gas, the Astrakhan gas plant is the largest producer of sulphur in Russia.

Russian sulphur output from Astrakhan has been stable since the 1990s at around 4.0-4.5 million t/a, with Orenburg contributing another 1 million t/a. Astrakhan's output is mainly sent to domestic markets, marketed by Gazprom Sera, and Orenburg's exported via Gazprom Export. The two plants between them represent about 85% of Russia's sulphur production. Gazprom produced 5.0 million t/a of sulphur in 2020, according to company statistics, down from 5.4 million t/a in 2019. This contributed to Russia's overall decline in sulphur production to 6.3 million t/a in 2020, a 6.6% fall, with refineries increasing output. Exports of sulphur were 2.6 million tonnes in 2020, down 20% on the previous year, due to difficult market conditions caused by covid. Major export destinations were Brazil, Israel, USA, China, Lithuania, Belarus, and Morocco, as well as some sales to El Salvador, Mexico, Benin and Jordan.

While the Astrakhan and Orenburg fields are mature, there is considerable interest among Russian energy companies in developing offshore fields in the Russian sector of the Caspian Sea, which may have reserves of up to 270 million tonnes of oil and 500 bcm of natural gas. This has been boosted by 2018's Caspian Sea Agreement, which resolved many issues as to access and ownership of subsea assets that had carried over from the breakup of the Soviet Union. Gazprom has two major developments in the region: the onshore Imashevskoye field near Astrakhan, which crosses the border into Kazakhstan and which is being developed by a joint venture called KazRozGaz; and the Tsentralnoye oil, gas and condensate field in the centre of the Caspian Sea, which is being developed by Gazprom, Lukoil and KazMunaiGaz. Imashevskoye gas totals around 100 billion cubic meters, with a sulphur content of 15-17%. However, development remains at an early stage.

Elsewhere, Lukoil extracts oil from the Vladimir Filanovsky offshore field, to the tune of around 6 million t/a, and is developing the Yuri Korchagin field. Vladimir Filanovsky is the largest oil field in the Russian sector of the Caspian Sea, and had initial recoverable reserves of 129 million tonnes of oil and 32 bcm of gas. Associated gas is processed at Stavrolen, where capacity is being expanded with a second train to 5 bcm per year, but the field is relatively sweet (0.1% sulphur in the oil) and volumes of sulphur are consequently modest.

## Azerbaijan

Is a significant oil and gas producer. Oil mainly (ca 80%) comes from the offshore Azeri-Chirag-Gunashli (ACG) field, which produces sweet (0.16% S) oil for export. However, production peaked in 2010, and has dropped by 40% since then. Most oil is exported, with only one significant refinery in the country, at Baku, where state oil company SOCAR has 120,000 bbl/d of capacity. Most of Azerbaijan's 60 tcf of natural gas reserves, meanwhile, are in the offshore Shah Deniz gas and condensate field in the Caspian Sea, which is being developed by BP. Gas production began in 2006 and increased with the start-up of Phase II in 2018. Gas is brought ashore for processing at the Sangachal terminal 55 km south of Baku, but the $H_2S$ content is only around 500 ppm.

## Kazakhstan

As mentioned in the Russia section, above, Kazakhstan's gas processing was closely connected with the Orenburg and Astrakhan plants in Russia. However, during the 1980s and 90s, the discovery of large onshore and offshore oil and gas fields in and around the Caspian Sea led to domestic developments there, at Karachaganak, Tengiz, and finally Kashagan.

The onshore Karachaganak field, near the Russian border, was the first to be developed, with oil production beginning in 1984. It is operated by the Karachaganak Petroleum Operating (KPO) consortium, with partnership from ChevronTexaco (18%), Agip and BG (29.25% each), Lukoil (13.5%) and KazMunaiGaz (10%). It is the largest gas producing field in Kazakhstan, accounting for some 30% of the country's total gas production. The field's total hydrocarbon output stood at 143.9 million barrels of oil equivalent (mboe) in 2020, and KPO achieved its highest ever annual production of 10.9 million t/a of liquid hydrocarbon production that year. However, about 50% of the gas produced (10.4 bcm in 2020) is reinjected to maintain pressure or used as fuel gas, while gas and condensate with a sulphur content of about 0.9%, is routed across the border to be processed at Orenburg in Russia, and hence forms part of Russia's sulphur output. While work continues on Karachaganak, including the recent Karachaganak Debottlenecking Project and Karachaganak Expansion Project, the latter completed in March 2021, these raise liquids production by additional acid gas reinjection, and do not generate additional sulphur.

During the 1990s and 2000s, most of Kazakhstan's sulphur came from the Tengiz field, on the northeast shore of the Caspian Sea. Total recoverable oil is estimated at 1 billion tonnes. It is operated by the Tengizchevroil (TCO) joint venture, formed in 1993 between ChevronTexaco and the Republic of Kazakhstan, with the current shareholding being Chevron 50%, ExxonMobil 25%, KazMunaiGaz 20%, and Lukoil 5%. Sulphur output from associated sour gas processing ran at around 1.6 million t/a in the 2000s, initially mainly poured to block storage, until issues with fugitive sulphur dust led to a government about turn on storing sulphur and a major fine, followed by several years of melting down and selling off the sulphur stockpile, which peaked in 2006 at 9.2 million tonnes, but which was essentially depleted by 2015. From 2006 there was also a programme of acid gas reinjection into the reservoir as part of the Second Generation Project to cut flaring and boost output, which also increased output from the sulphur plant to

PHOTO: GAZPROM

*The Astrakhan gas processing plant.*










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Fig. 1: **Oil and gas infrastructure in Central Asia**


around 2.4 million t/a. TCO sells almost all of the sulphur that it produces these days; around 2.5 million t/a in 2020. Sulphur sales to end-September 2021 were another 1.9 million tonnes. It sells both liquid sulphur by rail car, and granulated and crushed bulk sulphur to customers in Kazakhstan and overseas. Most domestic customers are based around uranium processing. Sulphur travels by rail across Russia to export ports, or east to China. Last year TCO completed a second sulphur granulation facility using Enersul technology with a capacity of 480,000 t/a, to enable it to convert all of its liquid sulphur output into granules as required. In terms of TCO project expansions, there is a long term Future Growth/Wellhead Pressure Management Project, currently about 80% compete, which will boost oil output by another 260,000 bbl/d to 850-900,000 bbl/d, but this will involve 100% sour gas reinjection.

Finally the most recent project to begin operations in Kazakhstan is the offshore Kashagan oil and condensate field, operated by the North Caspian Operating Company (NCOC), which includes ExxonMobil, Eni, Shell, Total and KazMunaiGas (KMG), each with a 16.8% stake, as well as Japan's Inpex with 7.56%, and the China National Petroleum Corp (CNPC). Kashagan has been a large and complex development, with technical factors complicating the project including high concentrations of $H_2S$ in the oil and associated gas (ca 17%). Corrosion caused by $H_2S$ meeting water in the pipelines led to it being shut down for repairs until 2016. About half of the associated sour gas is reinjected into the wells to maintain pressure, but the rest is processed onshore at the Bolashak gas sweetening plant. Sulphur production at capacity is around 1.2 million t/a. An expansion is in train at Bolashak to increase capacity, allowing for additional oil production from the field – dealing with associated gas is the major hurdle to increased oil production, which was supposed to be 450,000 bbl/d in the first phase, but is running at only around 300,000 bbl/d. The new train is due to be completed in 4Q 2023, and will include an additional 210,000 t/a of sulphur production capacity. Kashagan exports formed sulphur mainly by rail northwards to the port of Ust-Luga near St Petersburg in Russia, a considerable distance.

Of course, at present the major concern for Kazakhstan is the political unrest that has rocked the country at the start of 2022, caused initially by protests over fuel prices. The unrest has led to Russia sending troops to back the government as part of a mutual defence organisation, the Collective Security Treaty Organization (CSTO), in which Kazakhstan partners former Soviet states Russia, Belarus, Tajikistan, Kyrgyzstan and Armenia. The protests have centred on the capital Almaty, in the east of the country, and the Caspian region appears relatively unscathed so far, but the outcome of the protests appears highly uncertain at present.

## Turkmenistan

Turkmenistan, south of Kazakhstan, also borders the Caspian Sea. It is a relatively modest holder of oil reserves, and produces only around 220,000 bbl/d, mostly for domestic use. However, it is the world's fourth largest holder of natural gas reserves, after Russia, Iran and Qatar. With relatively low levels of gas demand, development of natural gas production for export has been seen as a way of monetising those reserves, but disputes with Russia over pipeline access slowed development in the 1990s and 2000s. Turkmenistan turned to gas-based projects which could export more easily transportable solids or liquids instead, including two urea plants and a gas to liquids facility that began operation in 2019. But new money for gas investment ended up being provided by China during the 2010s, and gas production increased to 66 bcm per year in 2016, though stagnating slightly to 60 bcm by 2020, with around half of that exported to China, as well as smaller quantities to Russia and other CIS states.

About half of Turkmenistan's gas comes from a series of fields that make up the Galkynysh reservoir, including South Yolotan, Osman, Minara and Yashlar. Production from the field began in 2013, and amounts to around 30 bcm per year, with a significant (about 6%) content of $H_2S$. The Galkynysh (formerly South Yolotan)







Table 1: **Central Asian oil, gas and sulphur production, 2020**

| Country | Oil output, million bbl/d | Refinery throughput, million bbl/d | Gas production, bcm | Sulphur production, million t/a |
|---|---|---|---|---|
| Azerbaijan | 0.72 | 0.12 | 25.8 | <0.1 |
| Kazakhstan | 1.81 | 0.37 | 31.7 | 3.7 |
| Russia | 10.67 | 5.50 | 638.5 | 6.3 |
| Turkmenistan | 0.22 | 0.12 | 59.0 | 1.2 |
| Uzbekistan | 0.05 | 0.06 | 47.1 | 0.2 |

*Sources: BP, Gazprom, TCO, NCOC, Russian Federal Service of State Statistics.*

gas processing plant has the capacity to produce 1.8 million t/a of sulphur. Production in 2020 was about 1.1 million tonnes. However, further development of Turkmenistan's gas has become mired in disputes with China over payment. China takes discounted gas in payment for the loans it made to develop the field, but Turkmen ministers have accused China of "profiteering", and plans to triple capacity to 95 bcm per year remain in abeyance for now.

## Uzbekistan

Uzbekistan, south and east of Kazakhstan, is a relatively minor oil and gas player. Its oil reserves are comparable to Turkmenistan, but its gas reserves are much smaller. They are however, sour, and so processing of gas and condensate from the Kandym, Kuvachi-Alat, Akkum, Parsanal, Khoji and West Khoji is processed at the Kandym sour gas plant in Uzbekistan, which began operations in April 2018. It processes 8 bcm per year of gas and produces about 180,000 t/a of sulphur.

## Iran

Finally, mention should be made of the other state which borders the Caspian Sea; Iran. Although Iran has faced crippling sanctions for many years, and poured its gas development efforts into the huge South Pars field in the Gulf, with the winding down of the South Pars development project and the signing of the new Caspian Sea Agreement, Iran has begun to look northwards again. Last year, Iran's Khazar Exploration and Production Company (KEPCO) said that it was exploring the Chalous structure in the South Caspian, which could be the second largest natural gas block in the Sea, with reserves 25% of South Pars, making it the 10th largest gas field on earth. If the estimates are accurate and the operation to explore the Chalous structure proves successful, the volume of recoverable gas could be 1.5 times total recoverable gas in Azerbaijan and the equivalent of 30% of the total recoverable gas in the Caspian Sea. More recent estimates suggest that the field may even be double that size, with 7.1 tcm of gas in place.

Following a 20-year deal with Russia that covers political, security, military, defence and economic cooperation, Iran has been in discussions with Russia and China over development of the field, with a proposal seeing Gazprom and Transneft taking a 40% share of output, CNPC 28% and KEPCO 25%. The remaining 7% would go to other Iranian firms connected with the Revolutionary Guards Corps. Gas could be fed into the Russian pipeline system for export to Europe, although the currents sanctions regime would probably preclude that.

## Sulphur demand

As Table 1 indicates, the main regional sources of sulphur remain Russia, with 5.0 million t/a of production from the Caspian area in 2020, mostly from sour gas and condensate processing at Orenburg and Astrakhan; and Kazakhstan, with production 3.8 million t/a mostly from TCO and Kashagan. Turkmenistan adds another 1.1 million t/a from Galkynysh. Set against this 10 million t/a or so of sulphur, regional demand remains relatively limited. At the moment there is phosphate processing in southern Russia, mainly PhosAgro, including its subsidiaries Ammophos and Balakovsk, and some industrial sulphuric acid plants which together consume between 2.5 million t/a of sulphur for sulphuric acid manufacture, and these are generally supplied from the Orenburg and to a lesser extent Astrakhan gas plants.

Kazakhstan's uranium mining industry has also become a major regional consumer, as large volumes of sulphuric acid are required to leach uranium oxide from relatively alkaline carbonate rocks. Kazakhstan's uranium output increased dramatically during the early 2010s, and stood at 22,800 tonnes $U_3O_8$ in 2020, representing 43% of all uranium mined that year, according to the World Nuclear Association. Production of this amount of uranium consumes about 1.5 million t/a of sulphuric acid. Some of this acid comes from smelter off-gases, but there are also three sulphur-burning acid plants with a combined capacity of 850,000 t/a of acid, representing a potential 280,000 t/a of sulphur consumption.

Kazakhstan also has phosphate deposits, and Russian fertilizer producer EuroChem is building a new plant in the Karatau region which will take sulphuric acid demand to 1.0 million t/a in 2022. Turkmenistan has a 500,000 t/a sulphur burning acid plant to feed DAP production at the Turkmenabat chemical complex, with the sulphur supply coming from Galkynysh. Uzbekistan has 650,000 t/a of acid capacity. However, these plants collectively cannot match the large volumes of sulphur being generated by sour gas production. Even added to regional Russian consumption, this leaves a surplus of over 6 million t/a of sulphur in the Caspian and surrounding region.

## Export issues

Central Asia sits at the centre of the largest continent, making it a long trip to deep water ports, mainly via rail across continental Russia to e.g. Ust Luga on the Baltic Sea. Russia is practised in making this long logistical link work, and exported 2.3 million t/a of sulphur in 2020, though this is considerably down on volumes for previous years. The Kazakhstan-based companies use some of the same routes, though also export east into China. However, winter closes river routes with ice and makes overland transport more difficult, and the combination of climate and distance make the costs of transport a significant barrier to exports of sulphur, especially at times of low prices. With the Kazakh government still set against long term block storage, it means that producers often turn to acid gas reinjection in preference to recovering sulphur.







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# The impact of US duties on phosphate markets


Import duties on phosphates from Morocco and Russia imposed by the US government in 2021 have compounded a lack of availability of phosphate fertilizer caused by Chinese export restrictions and led to higher prices for US farmers. Are there knock-on effects possible for sulphuric acid demand?

*Above: The Al-Jalamid phosphate plant, Saudi Arabia.*

Phosphate prices soared during 2021 after being in a relatively settled range for most of the previous few years. For example, Tampa f.o.b. DAP prices swung between around $300/t and $500/t between 2013 and 2020 (see Figure 1), before climbing to levels above $800/t by the end of 2021. One of the main factors in this, at least in the US, has been the decision by the country's International Trade Commission (ITC) to impose tariffs on imports of phosphates from Morocco and Russia, the second and fourth largest exporters of processed phosphates, respectively.

The decision stems from a case which was brought in June 2020 by US fertilizer producer Mosaic which alleged that phosphate producers in Morocco (i.e. OCP – Office Cherefien des Phosphates – the state phosphate monopoly) and Russia – essentially EuroChem and PhosAgro – were competing unfairly because of a series of hidden subsidies on their product. Investigations and a hearing were conducted during 2020 and completed in February 2021, and a final determination made in March 2021.

## ITC investigation

The evidence presented by Mosaic included an increase in phosphate fertilizer imports into the US from Morocco and Russia from 2.0 million st/a in 2017 to 3.0 million st/a in 2018, before decreasing to 2.7 million st/a in 2019, for an overall increase of 37% between 2017 and 2019. This happened in spite of an overall decline in demand for phosphate in the US in 2018-19 due to flooding of fields caused by exceptionally heavy rains and prolonged river closures along the Mississippi River system in 2019 that stranded fertilizer barges and resulted in delayed, destroyed, or abandoned plantings, especially in the Midwest and Great Plains regions. Mosaic further argued that the reason for the supply increase was that phosphate from overseas was sold at prices below cost due to subsidies in both Morocco and Russia.

Counter-arguments were presented, including the decrease in North American phosphate supply caused by Mosaic's decision to idle its Plant City facility in December 2017, and Nutrien's announcement in February 2018 of the conversion of its Redwater facility in Canada from phosphate to ammonium sulphate production. In March 2019, Mosaic also announced a 300,000 st curtailment in production, and in September 2019, it temporarily idled operations at its facilities at Saint James (Faustina) and Uncle Sam, Louisiana, reducing production by 500,000 st until they were restarted in December 2019.

The overseas producers also argued that their production costs were lower




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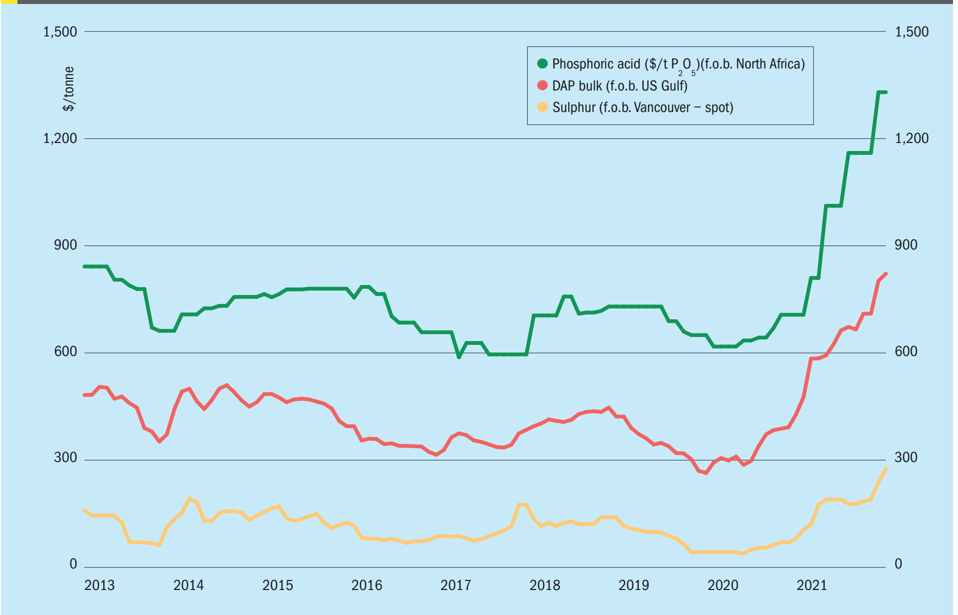
Fig. 1: **Prices of phosphates and sulphur since 2013**




*Source: Fertilizer International*

than US producers, but the Commission said that in its opinion, soft government loans to OCP, as well as various tax and duty exemptions, counted as subsidies, likewise it also regarded tax incentives and regional government subsidy programmes in Russia as subsidies to production cost.

However, while the action was launched to protect the US phosphate industry, it was not welcomed by end-use consumers in America. In a letter sent to the ITC on February 17th, 2021, the American Soybean Association, National Corn Growers Association, and National Cotton Council said: "While many row crop farmers have observed recent increases in fertilizer prices with concern, the greater problem caused by Mosaic's petition is that these duties are adversely impacting availability of phosphate fertilizer in the United States. Additionally, these duties reduce competition and choice available to farmers in the US marketplace." On March 1st, 11 US senators from corn belt states wrote a similar letter to the ITC.

Notwithstanding these pleas, on March 11th, 2021, the US ITC Commissioners ruled 4-1 in favour of Mosaic, and determined that imports had affected the US market, and proceeded to impose countervailing duties on imports of phosphate fertilizer. The duties imposed were 19.97% for Morocco's OCP, 9.19% for PhosAgro, 47.05% for EuroChem, and 17.2% for all other Russian phosphate producers. The duties will be reviewed in five years. The US already operates tariffs on Chinese phosphate producers, leaving only an estimated 15% of the global phosphate market open to US farmers without some form of import tariffs, according to the National Corn Growers Association.

## Price impact

Prices of phosphates have certainly spiked since then, and the temptation in the US has been to blame the new import duties. However, phosphate markets have also faced a number of other factors which make untangling the effect more difficult, including increasing grain prices and demand for phosphate fertilizer globally, sharply increased costs for ammonia due to high gas prices, which impacts MAP and DAP costs, and restrictions on phosphate exports from China.

In September 2021 China, which accounts for about 30% of the world's trade in phosphates, said it would not export phosphate until at least June 2022 in order to assure domestic supplies. Fertilizer prices hit record levels in China in 2021 because of strong demand, high energy costs and reduced domestic production, including flooding in Henan province, where the phosphate industry is concentrated. Although the US does not buy much phosphate from China, countries such as India and Australia do, and in the absence of Chinese supply they have been buying from other sources which has reduced availability for US imports. US phosphate production in 2020 was 24 million t/a, with imports running at about 2-2.5 million t/a. Chinese exports total around 5 million t/a.

The situation was exacerbated in November 2021 by Russia's decision to impose quotas on exports of fertilizer. Prime Minister Mikhail Mishustin said that the Russian government would introduce quotas to run from December 1st 2021 to May 31st 2022 on the exports of nitrogen and complex fertilizers. The former, mainly urea and ammonium nitrate, would be limited to 5.9 million tonnes, and for MAP, DAP and NPKs the limit would be 5.35 million tonnes. According to Mishustin, from December 2020 to May 2021, Russia exported 6.8 million tonnes of nitrogen fertilizers and 5.7 million tonnes of NP and NPK fertilizers.

## Blame game

All of these factors have combined in something of a perfect storm for the phosphate market, with, as noted, US Gulf DAP prices now over $800/t f.o.b., a level not seen since 2009. However, angry farmers in the US continue to point the finger of blame at Mosaic for the price rises, due to the ITC duty increases. In December, Iowa Senator Chuck Grassley sent a letter to Attorney General Garland calling on the Department of Justice (DOJ) to investigate possible anti-competitive activity and market manipulation in the fertilizer industry. He was backed by the National Corn Growers Association, whose president, Chris Edgington, said: "There is no reason that corporations like Mosaic Co. and CF Industries should be using the government to expand their monopolies at the expense of farmers."

In response, Mosaic has pointed to rises in raw material costs, noting that 2021 has seen the cost of ammonia increased 288% year-on-year, and sulphur prices rising by 165%, as well as the export restrictions from China and Russia as the main drivers of rising phosphate prices in the US and worldwide. It also argues that phosphate prices in the US are currently $20-100 per ton lower than in other major agricultural markets such as Brazil, India, and Europe.

## Effect on demand

According to the International Fertilizer Industry Association (IFA), global phosphate demand increased by 7.0% in 2020 to 49.6 million t/a $P_2O_5$. Phosphate rock production reached 207 million t/a, down slightly on the previous year, while phosphoric acid production was slightly up at 87 million t/a. CRU says that phosphate demand rose by 1.2% in 2021, and had been forecasting a rise of 2.9% for 2022. However, the current run of high prices seems bound to cause demand destruction, especially in the United States, the third largest consumer of phosphate after China and India. Rabobank has forecast a 10% fall in US phosphate application in 2022. While nitrogen must be applied on an annual basis, phosphate fertilizer can be left for a year *in extremis* with only a relatively small immediate impact on crop yields. The 2008-9 price spike saw a 32% fall in US phosphate application, for example, although higher crop prices may mitigate against that this year.

The effect could be more pronounced in other major consumers, such as India. According to the Indian Ministry of Chemicals and Fertilisers, only 910,000 tonnes of DAP was sold in the country in October 2021, against a projected requirement of 1.8 million tonnes. The figure for November was slightly better, but availability was still down 21% on projected requirements.

Of course, a major drop in phosphate demand could have a significant impact on sulphuric acid demand; a 10% fall in phosphate fertilizer demand could reduce acid demand by 5%. At the moment it's a good time to be a phosphate fertilizer producer, with record earnings likely for 2021 in spite of higher input costs. However, current price levels are not sustainable over the longer term without some level of demand destruction. ■





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# Refineries and the energy transition

Chevron's El Segundo refinery, California.

PHOTO: KEN MEAD/WIKIMEDIA COMMONS

As the world looks to a lower carbon future, refineries are having to examine their operating models, and look to, for example, renewable hydrogen production for desulphurisation technologies.

As international attention begins to focus more and more upon the potential threat posed by climate change, as witnessed, for example, at the UN COP-26 conference in Glasgow last October, so the fossil fuel industry, source of 95% of the world's sulphur, finds itself increasing in the crosshairs of governments and regulators. At stake is a transition to a lower carbon model of living, envisaging a transformation of the global energy sector from largely fossil-based to zero-carbon by the second half of this century. And amongst the key goals of such a transition is a move from diesel and gasoline powered vehicles to biofuel or electric power trains. However, oil majors were conspicuously absent from COP-26; told, according to Shell CEO Ben van Beurden, that they were "not welcome". So what does this mean for refiners? Although Shell and BP have both said that they aim for their operations to be carbon free by 2050, it seems clear that many governments, especially in Europe, are working on much shorter timescales, and refiners are likely to have to make considerable changes to their operations over the next decade if they are to remain operating.

## Hydrogen

Aside from ammonia and methanol production, refineries are the key producer and user of hydrogen. With hydrogen set to play a major role in the energy transition, in some ways this places refiners in an advantaged situation, as already being used to handling and distributing hydrogen, and given them an expertise which could be a valuable lever. However, it is likely that over the next decade or two, refiners will be gradually forced to lower their carbon footprint is by switching from natural gas or naphtha feedstock for hydrogen production to greener methods.

Europe has been at the forefront of such moves. In Germany, one third of refiners are said to be moving towards some form of green hydrogen production. Shell's 140,000 bbl/d Wesseling refinery began using 10 MW of electrolytically generated hydrogen in July 2021, though this will generate only 1,300 t/a of hydrogen. BP is planning to instal a 50 MW electrolyser at its Lingen refinery, powered by offshore wind from Ørsted, which will generate 9,000 t/a of hydrogen and replace 20% of the refinery's hydrogen requirement. At Westküste, a 700 MW green hydrogen project is planned for 2030, powered by an offshore wind farm, with the Heide refinery one of the partners in the project consortium. Heide is planning a 30 MW electrolyser as an interim step, in 2025.

Meanwhile, India has also announced plans to force refiners to use some green hydrogen. The draft National Hydrogen Mission policy, prepared by the Ministry of New and Renewable Energy, would mandate that green hydrogen account for 10% of the overall hydrogen needs of refiners from 2023/24, rising to 25% in five years. Reliance Industries, which runs the world's biggest refining complex at Jamnagar in western India, says that it plans to invest $10.1 billion in clean energy over three years in a drive to become a net carbon zero company by 2035, via four 'giga factories' at Jamnagar to produce solar cells and modules, energy storage batteries, fuel cells and green hydrogen.

However, financing such investments is an issue. There are some government incentives available. The Shell Wesseling refinery secured €10 million ($12 million) in funding from the EU through the Fuel Cell Hydrogen Joint Undertaking initiative, but there are several industries competing for grants to decarbonise, from steel to chemicals such as ammonia or methanol, and a limited pool of grants. Equally, the EU carbon market offers some incentive. EU carbon prices soared last year, from €32.72/ tonne of carbon dioxide equivalent at the start of the year, to a peak of €90.75/t$CO_2$e in December. High European prices for natural gas also help encourage a move to alternative methods of hydrogen production.

But there is also the question of how long the payback time for any large scale investment in green hydrogen generation is expected to be. The energy transition, particularly the shift to electric vehicles, threatens to undermine demand for transportation fuels within a decade or sooner. The UK has brought forward plans to ban sales of fossil fuel powered vehicles to 2030, and the EU is targeting 2035. BP says that its energy transition plan envisages cutting refining throughputs from 1.7 million bbl/d today to 1.5 million bbl/d in 2025 and 1.2 million bbl/d by 2030. Shell says it will divest itself of five of its 11 refineries by 2025, integrating the rest into large complexes.

> "The UK has brought forward plans to ban sales of fossil fuel powered vehicles to 2030."

## Chemicals

One of the potential solutions is to see hydrogen generation not just as a tool for hydrodesulphurisation of fuel components, but as a business in its own right. It might also be a way into using $CO_2$ for chemicals or even fuels production, perhaps via Fischer-Tropsch polymerisation, or methanol production with downstream processing into gasoline, or olefins. As we mentioned in our July/August issue last year, integration of refinery operations with chemicals production is becoming an increasingly attractive option for refiners. ExxonMobil says that almost 80% of its 4.5 million bbl/d refining capacity is now integrated with chemicals or lubricant manufacturing.

## Carbon capture

Perhaps a cheaper way of achieving lower carbon emissions is a move to so-called 'blue' hydrogen, using conventional feedstocks but capturing the carbon dioxide emitted and sending it to storage (CCS) or using it for something else. This offers the possibility of large scale installations (>1,000MW) without the expense of electrolysis. ExxonMobil has been a big advocate of CCS. The company says it plans to invest $15 billion over the next six years in reducing its carbon emissions, and CCS forms a major part of this. It is working with several other companies in supporting a large-scale CCS hub in the Houston area, where 15% of US oil refining capacity and 40% of petrochemical processing capacity is located. The hub could capture up to 100 million t/a of $CO_2$ from refineries, chemical plants and power generation facilities. Other major international players are looking to CCS, including Petronas, Pertamina, Rosneft and Saudi Aramco. Saudi Arabia, the world's largest oil exporter, has said that it is targeting 2060 for achieving carbon neutrality, with initial investments of more than $187 billion.

But the technology remains new and tetchy. High pressure $CO_2$ can be highly corrosive if it encounters water. Chevron announced in November 2021 that it had failed to meet a five year CCS target at its $3 billion Gorgon LNG project in Western Australia, and was buying A$40 million ($29.17 million) in carbon offsets to compensate for more than 6 million tonnes of carbon emissions, after only managing to capture 30% of what it had promised.

## Biofuels

Production of biofuels is also another way forward for refiners, processing waste biomass or vegetable oils. Total says that its bio-refining operations have actually performed better financially than its conventional refineries since the start of the covid pandemic. The company has converted its 160,000 bbl/d La Mede refinery in France into a 500,000 t/ya hydrotreated vegetable oil plant, and says that it will end conventional refining at its 93,000 b/d Grandpuits facility near Paris this year, converting it to a biorefinery by 2024. Meanwhile Chevron began co-processing bio-feedstock in the FCC of its El Segundo refinery in California in 2021 using 2,000 bbl/d of soybean oil. This year, the plan is to convert the diesel hydrotreater to 100% renewable capacity, increasing capacity to 10,000 bbl/d of renewable diesel, rising to 100,000 bbl/d by 2030. Phillips 66 is looking to do similar, converting its Rodeo refinery at San Francisco in California from crude oil, to a variety of renewable feedstocks to produce lower-carbon transportation fuels by 2024.

Greater use of vegetable oil processing could also have an impact on hydrogen demand. According to IHS Markit, wider use of hydrotreated vegetable oil (HVO) as fuel would boost hydrogen consumption as the HVO biofuel process requires large amounts of it to remove the oxygen from the feedstock and isomerise the hydrocarbon chains. But large scale adoption of vegetable oil, even waste oil, has impacts upon the food sector, and would not be scalable to form a large fraction of transportation fuel needs.

## Other tactics

In addition to the measures above, there are other ways that refiners can hedge themselves against the changes that are coming to the industry. The first and perhaps most obvious is to focus upon the most efficient and profitable assets, divesting standalone facilities and upgrading and integrating the best refining assets. Secondly, investment in digitalisation and process analytics should pay dividends in being able to optimise production, reduce expenses and increase margins. Finally, some refinery product sectors seem set to continue to grow rather than shrink – for example, aviation fuel is difficult to replace with alternate fuels and demand should continue to grow once the worst of the covid pandemic passes.

## The sulphur block

The impact on refinery sulphur output will depend on the specifics of each technology used. In general, changing the hydrogen feed to 'green' or 'blue' from the present 'grey' is unlikely to impact much upon refinery output. Greater processing of biomass feeds however is likely to lead to higher $CO_2$ but lower $H_2S$ levels in the acid gas, and much lower sulphur recovery levels, possibly down to levels that would be treated with a scavenger rather than a Claus plant.





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# Sulphur + Sulphuric Acid 2021

A look at papers presented at CRU's annual Sulphur + Sulphuric Acid conference, which was once again held virtually, in November 2021.

As with last year, the continuing shadow of coronavirus hung over international meetings and travel, once again necessitating a 'virtual' Sulphur + Sulphuric Acid conference at the end of last year. CRU's tried and tested conference application worked well once again, though I for one hope that we will be able to return to face to face meetings later in 2022.

The familiar structure of commercial presentations followed by technical was preserved, and Peter Harrison as usual kicked off the conference with his annual look at how the sulphur market has moved and might move in the future. Sulphur prices ran up at the end of 2020 and the start of 2021, he said, but remained stable for most of 2021, except for some freight related moves. However, the end of 2021 saw prices move up again dur to movements in sulphur consuming markets such as phosphates. Phosphate base demand growth is forecast to be strong throughout 2022-23, mainly in Morocco and Saudi Arabia, though it tails off thereafter to more 'normal' levels of 1.0 million t/a growth. The battery metals sector is growing very strongly, though from a low base, with both nickel and lithium consuming additional acid volumes. Indonesia's sulphur demand is forecast to double by 2025 due to new HPAL plants, and the US is adding lithium capacity which will consume an extra 1.2 million t/a of sulphur by 2030. Peter predicted that the rebound in sulphur demand would persist into 2022, with China substituting some pyrite based acid production for sulphur burning.

> "There could be 11 million t/a of acid demand from battery metals processing by 2025."

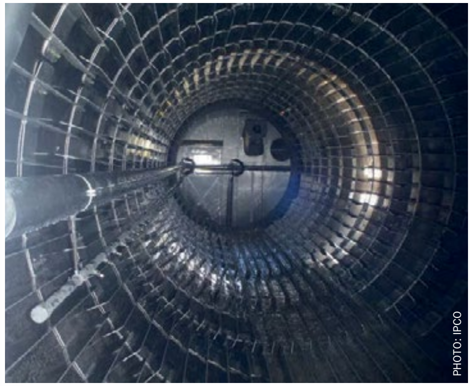
On the supply side, Europe's market is becoming tighter with falling supply from oil and German sour gas, meaning the continent may need more remelter projects. North American supply is recovering as refineries restart, though there has been disruption from storms in March and September and falling sulphur content of refinery crude inputs. Alberta sour gas production continues to fall but there is a rebound in British Columbia and some growth from oil sands. The Middle East remains the largest incremental producer, with new sulphur from Kuwait, Qatar and the UAE to come. China is also adding more sulphur from the Changdongbei sour gas project. Overall, Peter saw sulphur prices peaking in Q1 2022.

Peter's colleague Daly dealt with acid markets. Acid price increases outpaced related markets such as copper, nickel and phosphates during 2021, and have continued to climbed sharply during the year as supply tightness persisted. Because acid price gains have been higher than those in demand markets, affordability has weakened and there has been an incentive for those who are able to buy sulphur-burnt acid instead. However, Chilean import demand has remained strong in spite of the price rises, at 2.6 million tonnes in 2021, and lack of availability from Peru means imports from outside the region look set to be over 1 million t/a out to 2025. New phosphoric acid plants and the continuing absence of the Tuticorin smelter are also driving increased Indian acid imports. The US has also seen additional imports with more phosphate demand and smelter outages, and there is more demand on the horizon from new lithium projects. Meanwhile, on the supply side, the high prices have led to more sulphur burning exports from Two Lions and others in China. In the longer term, Brendan said, markets for battery metals like nickel and lithium would start to drive new acid demand from around the mid-2020s, in China, Australia, the US, Indonesia and others. The ioneer Rhyolite Ridge project in the US will alone consume 900,000 t/a of acid, and Brendan projected that there could be 11 million t/a of acid demand from battery metals processing by 2025. In the short term, however, he saw softening in the acid market for 2022 in both the Atlantic and Pacific basins.

The third of the non-technical presentations was a return for the familiar face of Peter Clark, formerly of ASRL, now professor emeritus at the University of Calgary. Peter took a longer term look at the impact of trends in energy markets on sulphur production. He wondered if the dip in sulphur production from refineries as fuel demand fell during covid at the same time that phosphate demand remained strong was a foretaste of things to come as we gradually move towards electrification of road vehicles and more renewable power generation. Coal represented 35% of energy generation in 2020, and nuclear, hydroelectric and other renewables 32%, with oil and gas most of the remainder. While the focus is currently on eliminating coal, probably requiring major investments in nuclear power in countries like India and China, oil and gas will not be far behind, and may see major falls in consumption from about 2030. Since they currently provide 95% of all sulphur, alternatives need to be found. Peter speculated about recovery of sulphur from gypsum ($CaSO_4$), supplies of which are "almost limitless".







*Inside an IPCO drum granulator.*

PHOTO: IPCO

However, a lot of 'green' electricity might be needed to do so. He foresaw a focus on phosphate recycling to ease the burden on falling sulphur availability, and possibly longer term an emphasis on population control.

## Sulphur

The sulphur technology strand began with a presentation by IPCO's Casey Metheral of his company's SG20 drum granulator. Like the larger SG30, the SG20 has a seed generation system – the solid sulphur seeds are then added to the granulator with the liquid sulphur to begin granule formation. It can be configured with either an angled drum, allowing gravity to move the granules, or a level drum with advancing flights. Spray nozzles are heated to avoid clogging with solid sulphur. A wet Venturi scrubber or steam jacketed cyclone removes sulphur dust, and in both cases the dust is remelted and recycled back to the drum. A bolt-on system for handling $H_2S$ emissions is also available.

Cyndi Teulon of RSK described a project in Iraq for handling $H_2S$ recovered as part of a gas flaring reduction project. The $H_2S$ is treated biologically using a thiobacillus bacteria, which converts it to 43 t/d of elemental sulphur. The sulphur produced is 98.9% pure, the rest being organic matter, with no hydrocarbons or heavy metals, and it was found to be suitable for use in agriculture. A series of assessments and finally field trials were conducted between 2018 and 2020 in the UK and Iraq, and found that the micro granules were quickly oxidised to sulphate without major impact on soil pH. Significant improvements in crop yield were found in sunflowers, okra and corn in a variety of different conditions. The project is now looking at bagging and distribution options and is working with Iraqi government and farmers to secure wider acceptance.

Sulphurnet looked at dealing with emissions of sulphur dust and $H_2S$ from sulphur melting facilities. These mainly occur from the melt and precoat tanks, and the company has developed a caustic scrubbing solution for vent gases which removes $H_2S$, which also removes microscopic sulphur dust for collection to tank for filtration, recovery and remelt.

Rohan Prinsloo presented some of Alberta Sulphur Research's latest work; carbon disulphide destruction using commercial alu-





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mina or titania in a liquid phase sulphur recovery process. The process is a proof of concept for liquid phase sulphur recovery from Claus tail gas, using a mix of biphenyl and diphenyl ether. However, the Claus process can generate $CS_2$ from methane or methyl mercaptan. It is removed by a catalytic hydrolysis reaction – the challenge is making it work at the ca 150C of the process working temperature. Using titania or alumina as a catalyst leads to 98% and 95% removal, respectively, and ASRL's work in the area continues.

## Case studies

Benoit Mares of Axens showcased the installation and start-up of a modular *Smartsulf* unit at the Jurassic facility in Kuwait. *Smartsulf* is a modified Claus process with two reactors, one in hot mode, and the second using sub-dewpoint operation. It has no standby reactor or regeneration loop, or tail gas treatment, but nevertheless achieves 99.5-99.7% sulphur recovery. The Kuwait installation was achieved in 17 months from award of the contract, using modular construction and fabrication in China, and assembly supervised by Axens.

Jan Klok of Paquell and Ellen Ticheler of Worley Comprimo described the installation of a *Thiopaq* unit in a refinery. The refinery was moving to a higher sulphur crude feed and could no longer rely on its previous scavenger-based recovery process, but only needed to recover around 3 t/d of sulphur from sour gas and sour water stripper gas. *Thiopaq's* biological process offered the refinery the turndown capacity that it was looking for.

Gerald Bohme of Sulphur Experts recounted a tail gas treatment unit upset, and stressed the importance of proper process monitoring, using analysers and indicators in combination and showing all of the analyser range on the control system, and understanding what a readout looks like when they are not working.

Elmo Nasato of Nasato Consulting recounted a catalogue of water-related issues in sulphur recovery units, mainly waste heat boilers and condensers, including flow-assisted corrosion. Practical solutions included controlling water purity and condenser water level, especially during shutdowns, when effective shutdown procedures can minimise corrosion. Regular inspection and eddy current testing can identify tube wall thinning.

## Sulphuric acid

On the sulphuric acid technology side, BASF began with a low $SO_2$ emission sulphuric acid catalyst development, presented by Jonglack Kim and Dirk Hensel. The Quattro catalyst has a quadrilobed shape for higher surface area at normal packing density. It also has lower propensity for chipping or attrition. Conversion is increased and capacity is around 8-10% higher. An installation in Brazil showed a 13% capacity increase and 222ppm lower $SO_2$ emissions.

Rene Dijkstra of Chemetics showcased the *CORE-SO2* process, which uses stoichiometric oxygen-based combustion of sulphur to achieve smaller plant sizes for a given capacity, as it allows the removal of some large equipment items such as dry towers, gas-gas exchangers, economisers and a final absorption system. Lower tail gas volumes lead to lower emissions. An improved $SO_2$ generation system is also currently being patented. And of course as with any acid plant, as part of a larger fertilizer complex, the power generated is carbon free, and could be used to generate hydrogen by electrolysis for ammonia production.

"The power generated is carbon free, and could be used to generate hydrogen by electrolysis for ammonia production."

Shailesh Sampat of SNC Lavalin also looked at energy recovery and efficiency from an acid plant and integration of it into a larger complex. For example, hot water can be used for washing filter cake in a phosphate plant, while steam, hot air and condensate can be used in pyrometallurgical plants concentrators, granulators and dryers, especially if the $SO_3$ cooler is replaced by a waste heat boiler to generate low pressure steam. Use of MECS HRS can also increase the energy recovered in an acid plant.

Joan Bova of CG Thermal addressed design considerations for sulphuric acid regeneration units, including vapour pressure, viscosity, materials of construction, bonded linings or retrolining for vacuum operation, and heat transfer in ceramics.

## Clark Solutions

NORAM Engineering detailed the process design considerations for a catalytic converter replacement, as well as the fabrication and transport and installation issues.

## Mist eliminators

Martyn Dean of Begg Cousland asked why you would want to wet mist eliminators in an acid plant. The answer was to control $SO_3$ emissions during start-up or shut down, control $SO_2$, which can lead to a visible plume from the stack and emission non-compliance, and to remove NOx which can contaminate product acid. A variety of ways of getting liquid $H_2SO_4$ onto the filters was presented, with case studies of their operation.

Though for reasons of timing it ended up in the sulphur section, CECO Filters also presented on their filters and mist eliminators for sulphuric acid plants.

## Plant operation

Marcelo Rios of DuPont Clean Technologies presented a case study of the application of DuPont's *Dynawave* tail gas scrubber at an acid plant in Chile. *Dynawave* can operate at any scale of acid plant, and remove acid mist and dust and alkaline gases such as ammonia as well as $SO_2$, $SO_3$, halides and halogens, using a variety of reagents according to selectivity and cost criteria. The operator selected it because of new emissions regulations which the plant did not presently meet, and the system is now operating efficiently.

Another Chilean operation was the topic for Ellio Barazza and Collin Bartlett of Metso Outotec. Noracid at Mejillones, founded in 2007, supplies the northern Chilean mining industry using a 720,000 t/a Outotec acid plant. It has achieved high reliability – only two days were lost to unscheduled outages in 2020, and availability was 98.5%, thanks to condition-based monitoring and maintenance. All critical spare parts are available on-site with automatic restocking. The plant is now moving towards a further digital optimisation of its operations.

Marcelo Chagas of Mosaic described a new catalytic configuration at the Araxa plant in Brazil, designed in conjunction with supplier Haldor Topsoe to reduce $SO_2$ emissions while maintaining lower pressure drop during start-up. Computer modelling led to peak $SO_2$ emissions being reduced by 40%.






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# SULPHUR index 2021

A complete listing of all articles and news items that appeared in *Sulphur* magazine during 2021.
















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# Key considerations for converter upgrades

Catalytic converters are the heart and hub of sulphuric acid plants. Converter replacement of equipment that has come to the end of its life is an opportunity to make improvements to the performance, productivity, reliability, durability and plant emissions. NORAM discusses design and project execution considerations for $SO_2$ catalytic converter replacement and Chemetics considers the challenges and opportunities of converter retrofits.

**NORAM**

## $SO_2$ catalytic converter replacement – design and project execution considerations

During the lifecycle of a sulphuric acid plant, there may be times when the performance of the plant needs to be improved e.g., to lower emissions of sulphur dioxide ($SO_2$). Although a number of process alternatives exist for performance improvement, typically the most cost-effective way is to upgrade the existing equipment such as the catalytic converter, which together with the catalyst is the heart of the plant and determines the $SO_2$ emissions from the plant.

Converter replacement is typically required at about 20-40 years of age depending on factors such as $SO_2$ gas strength, converter design and reliability concerns. Higher strength $SO_2$ feed gases to the acid plant result in higher temperatures and shorter converter life. Older converter designs with cast iron posts and grids with a carbon steel shell may see deformation of posts, wall thickness reduction, sigma phase embrittlement, and shell bulging, necessitating replacement. When there are concerns about the mechanical integrity of the converter, a prudent owner may decide to replace it rather than risking a major failure.

Other reasons for replacing the converter include:

- the requirement to increase catalyst volumes beyond the capacity of the existing converter;
- conversion from single to double absorption;
- combining two converter vessels into one.


PHOTOS: NORAM

*Fig. 1: Examples of converters assembled at fabrication shop, shipped in one piece, and lifted into place.*

Project considerations for a converter replacement include $SO_2$ emissions limits, specific tie-in points and dimensional limits, ergonomic requests, turnaround planning and duration of plant shutdown, existing equipment condition and logistics considerations. Design tools such as computational fluid dynamics (CFD) are used to evaluate velocity and temperature distribution in the catalyst bed and to confirm uniform gas distribution, whereas finite element analysis (FEA) is used for mechanical design.

NORAM's approach to converter replacement is to, where possible, make the converter in the shop and relocate on the same foundation (Fig. 1). For replacement converters NORAM typically designs the new converter diameter to be similar to the existing converter to match the foundation and tie-ins. Improved catalyst performance allows reduced emissions with the same diameter.





Although a new converter will typically improve the performance of the sulphuric acid plant, it cannot resolve upstream process issues. It is therefore important to ensure that the feed gas to the converter is within the design operating envelope to optimise performance, minimise emissions and maximise equipment life.

Good $SO_2$ concentration control to the first catalytic pass is required to maintain an acceptable temperature profile, while feed gas temperature control is required to prevent acid condensation on the catalyst. Effective mist elimination upstream of the converter is required to prevent mist carryover, which may result in damage to the catalyst, fouling and high converter pressure drop as well as equipment corrosion.

### $SO_2$ conversion

A well designed and operated converter (inclusive of catalyst) reduces $SO_2$ emissions from the acid plant. Emissions of sulphur dioxide are defined by the design of the catalytic converter, the production rate, catalyst selection (type, size, loading, volume, age and activity), operating temperatures and the interpass absorption tower efficiency.

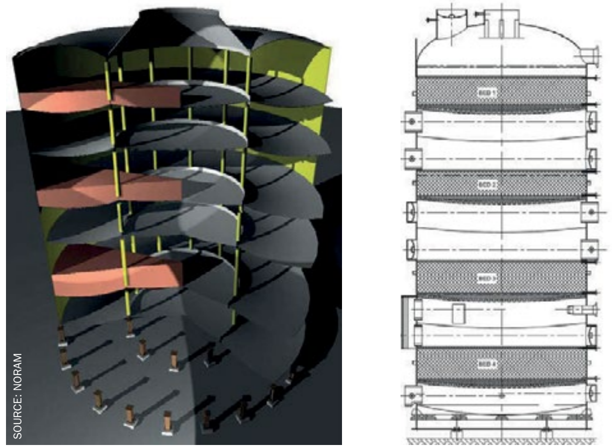
Approximate rules of thumb for $SO_2$ oxidation in the converter include:

- Temperature rise = % $SO_2$ converted times 28°C (50.4°F).
- Incoming $SO_2$ concentration = Total temperature rise in all four beds divided by 28°C (50.4°F).
- Conversion in first bed = about 60-65%.
- Maximum allowable temperature for the catalyst = 620 to 650°C (1,148 to 1,200°F)

There are two basic types of sulphuric acid catalysts, standard vanadium pentoxide and enhanced catalyst e.g., caesium-promoted catalysts. $SO_2$ emissions are also affected by the number of catalyst beds. Four catalyst beds are most common but other configurations are also available, for example, 3 beds or a 3+2 configuration.

The converter design will depend on the target emissions from the stack which are usually dictated by government regulations. An achievable target is 100-150 ppm.

Total $SO_2$ emissions from the acid plant are made up of the $SO_2$ leaving the converter plus contributions from stripping the acid in the final tower. Final tower $SO_2$ slippage is therefore an important consideration, especially if there is a common interpass and final tower pump tank. With this configuration, $SO_2$ will be transferred from the circulating acid in the interpass tower into the pump tank, from where it is transferred to the final tower where it will be stripped and end up as $SO_2$ emissions, contributing up to 50-70 ppm $SO_2$ to the total $SO_2$ gas concentration in the stack.



SOURCE: NORAM

*Fig. 2: Converters that fully utilise their cross-sectional area for catalyst loading. NORAM 3D model (left) and NORAM general arrangement (right)*

### Catalyst evaluation

Technical considerations when evaluating catalyst selection are based on the following:

- conversion per bed;
- inlet and outlet bed temperatures;
- pressure drop per bed;
- emissions in ppm.

Commercial considerations include:

- catalyst price;
- two-year warranty on conversion;
- pressure drop warranty at start-up;
- blower power cost over a 10 year period.

Rigorous comparison of quotes with identical design basis in terms of performance guarantees, catalyst conversion, pressure drop, and overall economics is required to identify the best fit.

### Converter design

The selection of the correct converter design can reduce the project cost and improve performance.

New equipment should have a robust mechanical design and provide reliable operation, higher on-stream time, and lower maintenance requirements than the existing converter. The converter should be fabricated using suitable material of construction such as stainless steel.

Designs should be robust and reduce high localised stresses which could lead to premature failure and gas leaks. Rectangular nozzles should be avoided. Nozzles should be obround, elliptical or round to minimise stresses. The new converter should be designed according to local climatic and seismic conditions.

Where feasible, dimensional constraints and requirements should be considered to minimise ducting changes.

A key aspect of NORAM's patented converter design is that it allows the use of the full cross-sectional area for catalyst loading (Fig. 2). However, if required, NORAM's design is also able to accommodate the installation of gas-gas heat exchangers in the core to reduce pressure drop and space. With one internal gas exchanger it is still possible to use the full cross-sectional area for catalyst loading in the remaining two or three beds. For replacement converters, this is a powerful feature that increases the cross-sectional area for the same diameter.

Also, by using a catenary plate design, NORAM can build the modules in the shop for high quality control and then weld the modules together in the field.





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### Converter sizing

Converters are sized based on a superficial gas velocity through the catalyst bed, plot space available, shipping constraints, and pressure drop. The catalyst bed total pressure drops should be above 2" (51 mm) WC to avoid gas maldistribution. Catalyst manufacturers specify a fairly wide superficial velocity range of 20-40 linear metres per minute at standard volume conditions.

A secondary consideration after conversion and pressure drop is shipping considerations and whether the size of the equipment is shippable in one piece. If the new converter size is very close to shipping limits it may be possible to reduce the size somewhat to make it shippable, provided it doesn't compromise process performance.

The converter height is determined by several factors. Catalyst depth is specified by the catalyst manufacturer, based on the process requirements and conditions and according to the catalyst volume and type. The prescribed catalyst bed height should include an allowance for future capacity increase or more stringent emission limits.

Headroom above the catalyst is sized for operators and maintenance to enable loading and screening of catalyst.

Clearance between catalyst support plate and division plate is often determined by outlet duct size and shape but with sufficient clearance for maintenance inspection.

The radial orientation of the ducting for the new converter can be easily matched with the existing converter but ducting elevations could vary. New converters are often taller with more room for catalyst and inspection.

### Pressure drop

Designing for lower pressure drop will reduce energy consumption of the main blower.

Converter pressure drop comprises:

- Nozzle pressure drops
  - Design for <20% of catalyst DP for uniform gas distribution
  - Typical pressure drop +/-12 mm (½ inch) W.C.
- Catalyst pressure drop
  - Determined by converter design, catalyst type, catalyst depth
  - Converter with core tube has higher pressure drop due to less cross-sectional area.
  - Typical clean pressure drop from 75-150 mm (3-6 inches) W.C.
- Catalyst support pressure drop
  - Support comprised of packing support plate, saddles, expanded metal, quartz rock or ceramic balls.
  - About 12 mm (½ inch) W.C.

## Converter configuration

### Internal exchanger

The hot or hot interpass (IP) exchanger can be installed in a new stainless steel converter. This eliminates external equipment including concrete, ducting, insulation and simplifies the plant layout. It is typically a standard offering for new acid plants.

### Manways and bypass ducts

Manways should be large, typically at least 1 m diameter to allow for personnel access (Fig. 3). There should be two above the catalyst bed, one for personnel access and the other for equipment access. The start-up bypass duct can be on the outside of the converter for faster start-ups.

### Refractory lining of the first pass

Some plants, more often sulphur burning plants, request to have refractory lining in the first pass of the converter (Fig. 4). Having a lining of insulating firebrick in the first pass of the converter provides additional heat retention so that when the sulphur furnace is shut down heat is retained for longer, allow for a longer shutdown before requiring fired heat input to start up again. It also offers some protection to the first pass outlet zone from the hot gases.

*Fig. 3: Manways and start-up bypass duct.*

*Fig. 4: Refractory lining of converter first pass.*

### Bed and division plate support options

Converters were initially designed with a carbon steel shell and cast-iron grids and cast-iron posts for support. In the 1980s stainless steel converters appeared, with either dished beds or stainless-steel beams and posts.

The dished bed has some advantages:

- reduces the weight of the stainless steel required;
- can accommodate an internal gas exchanger;
- no internal support need if the converter is less than 7 m (22 ft) in diameter;
- can be shipped in modules for site erection of components.

There are two support systems for dished bed converters larger than 7 m:

- a central cylindrical support reduces the cross-sectional area of the converter bed but allows radial gas flow from the core;
- a ring of stainless-steel posts allows the full cross-sectional area to be used and uses shell-side gas nozzles.

## Project execution

### Fabrication and shipping

After agreement on the design basis, size and shipping/construction strategy, NORAM will design and fabricate the converter.

Depending on the size of the converter it can either be shipped in one piece or in multiple pieces. (Fig. 5).

Shipping in one piece is preferred as it maximises fabrication in a controlled shop environment, minimising field work and its associated costs and risks.

Converters of up to approximately 4.5 m (14-15 ft) in diameter can be transported by truck. Larger diameter converters can be transported by barge or ship. This option is typically more expensive than truck and requires more lifts.

Converters of 4.5-5.8 m (14-19 ft) in diameter could be shipped in "rings". Converter rings require simple field erection. The number of circumferential field welds will be number of rings minus one.





*Fig. 5: Shipping in rings (above) and converter half ring (below).*

*Fig. 6: Replacement converter in a new location.*

Converters with a diameter larger than 19 feet can be built in sections and shipped in pieces (e.g., 180° half ring sections or 90° sections consisting of four pieces per ring) and assembled on site.

### Location of the replacement converter

There are two basic choices for the location of the replacement converter, using the existing foundation or a new location.

When using an existing foundation, prior to the shutdown, the new converter is erected or set near the existing converter. During the shutdown the converter is removed or demolished, and the new converter is lifted or wheeled in. It is preferable to insulate prior to shutdown if possible.

For a new location, prior to shutdown the new converter is erected or set on a new foundation and insulated (Fig. 6). New ducting is installed ready for tie-in. During the shutdown the new converter ducting is connected to the existing ducting. Finally, after start-up of the new converter the existing converter is demolished or moved.

Using the existing foundation is the preferred option in most cases. It retains the same plant footprint and requires less ducting changes but requires the ability to easily demolish and move the new converter into place and may require a longer shutdown.

Using a new location can reduce project schedule risk due to most of the work being done prior to the shutdown but is likely to be more expensive due to eight new ducts requiring connection with existing equipment. In addition, it changes the footprint of the plant and requires plot space relatively close to the existing converter to minimise costs.

*Fig. 7: Demolition and wheel out (left) and wheel in of new converter (right).*

### Demolition of existing converter

The main options for re-use of the existing foundation are to install beams under the converter and either lift, wheel or slide it out (Fig. 7). Alternatively, the converter can be demolished in place and taken apart in pieces.

### Installation of replacement converter

For re-use of the converter foundation, the following options can be considered during the shutdown for installation of the replacement converter:

- Lift In
  - Lift in insulated shell using lifting lugs on the top of the converter.
  - Typically install quartz rocks and catalyst after.
- Wheel or slide in
  - Wheel or slide in insulated converter onto the existing foundation
  - Catalyst and rocks may be installed before or after the move
- Erect in place
  - Converter modules are erected onto the existing foundation
  - The converter is insulated, catalyst and rocks installed.





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**CHEMETICS**

# Converter retrofits: challenges and opportunity

The global sulphuric acid industry is currently faced with challenges and opportunity simultaneously. Internal and regulatory requirements for lower emissions and greater efficiencies are commonplace. At the same time, the vast majority of global sulphuric acid plants are approaching the age where major equipment is reaching end-of-life and will need to be replaced. Catalytic converters are the hub and heart of any sulphuric acid plant and virtually all of the major plant equipment is directly connected to the converter. When the time comes to replace an old converter, it should be treated as an opportunity to implement and benefit from several possible improvements to the performance, productivity, reliability, durability, and emissions of the plant. Common achievable plant upgrade goals are as follows:

- increase the $SO_2$ to $SO_3$ conversion rate/lower $SO_2$ emissions;
- reduce the $SO_2/SO_3$ emissions due to internal and external ducting, nozzle or converter leaks;
- increase capacity;
- reduce pressure drop;
- simplify plant layout;
- improve equipment durability;
- minimise maintenance work and plant downtime;
- increase time between turnarounds.

Over 40 years ago Chemetics developed, patented, and presented the modern radial flow, all welded, stainless steel converter (Fig. 1) to the global sulphuric acid industry. This novel design helped achieve all the aforementioned goals for new plant and retrofit projects. Additionally, Chemetics has developed modular execution strategies to minimise site assembly/installation time, while also allowing the maximum location and layout options. This article explores the strategies and design elements that Chemetics applies to achieve the above goals on converter retrofit projects.

## Radial flow all-welded stainless steel converter

The introduction of the radial flow all-welded, stainless steel converter was a significant upgrade over the common original grid-and-post design. The all stainless steel construction provides a robust and lightweight converter without the need for any internal brick lining. The significant reduction in mass and inherent mechanical flexibility during times of large differential thermal expansion also results in reduced plant warm-up time for cold start-ups. All joints and seams are fully welded which eliminates any inter-bed leaks/bypass. The duct nozzles apply a proprietary design that allow for zero leaks to atmosphere, even after decades in service, thus eliminating a repetitive failure mode found on both historical carbon steel brick-lined grid-and-post converters, as well as their modern stainless steel grid-and-post replacements. The radial flow design applies a centre core to the converter (Fig. 2) that is used to feed gas radially from the centre core to each catalyst bed. This results in uniform gas distribution and complete and efficient use of the catalyst in the converter. Hot spots or high velocity areas that can lead to local catalyst degradation are eliminated. These features contribute to lower required catalyst loadings for the same plant performance and lower converter pressure drops. By comparison, the grid-and-post design is prone to inter-bed leak/bypass between the stacked components, particularly as the converters age and experience shift and internal settling (Figs 3 and 4). In addition, the grid-and-post converters feed gas to the beds from a single shell nozzle, this can result in non-uniform gas distribution.

Chemetics recommends designing converters with consideration for future potential capacity and emissions goals. With minimal additional investment, future catalyst capacity allowance can be included to address potential future needs. The Chemetics design leaves a completely open and accessible catalyst bed area. This allows very easy access for adding, changing, or screening catalyst.

The result of all the improvements that came with the Chemetics converter design have enabled acid plants to increase their $SO_2/SO_3$ conversion rate, reduce $SO_2/SO_3$ emissions due to internal and external leaks, minimise maintenance costs and plant downtime, and improve equipment durability and longevity. The proof is in the performance. Chemetics converters regularly have zero mechanical maintenance or external leaks for decades after installation.

Fig. 1: **Chemetics modern converter**

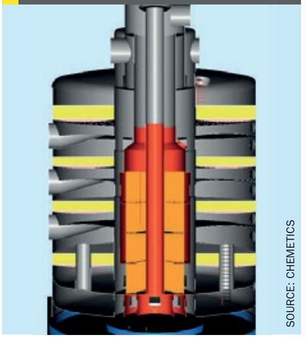



*Fig. 2: Chemetics core radial gas flow to catalyst bed.*


*Fig. 3: Failing posts.*


*Fig. 4: Shifting grids leading to gas bypass and catalyst drop.*





## Insulation

An underappreciated area that is crucial for converter performance is the insulation system. Unlike small vessels and ducting, the large size of the converter along with the very high metal temperatures results in drastic thermal expansion of the converter shell, but not in the cladding. For example, in a 30-ft diameter converter the shell will grow approximately 1-ft in circumference relative to the cladding. With a simple cladding system this leads to failures in the cladding weather barrier after multiple thermal cycles, and eventual water ingress and loss of effective insulation. To rectify this, Chemetics has developed a floating cladding insulation system that avoids cyclic stresses to keep the insulation system intact through decades. Poor insulation leads to fast heat loss, reducing both steam production and the duration of a practical hot shutdown. With an intact insulation system, hot standbys of over 16 hours are common.

## Catalyst selection and loading

The catalyst world is constantly evolving. Continuous advancements in composition and shapes create more options for greater overall or targeted performance (conversion, pressure drop, temperature window, durability etc.). In some circumstances certain improvements to existing plants/converters can be made by changing the type and/or loading of catalyst. However, this depends on whether the original design accounted for potential future additional capacity, and it often also requires significant alterations to other major process equipment such as gas exchangers and towers. When replacing a converter, the opportunity arises to design around the optimal available catalyst options and loading in order to achieve the plants current and future goals (emissions, plant capacity etc.). Although this will still often require changes to other process equipment, Chemetics treats this is as an opportunity to modernise and simplify the plant layout and achieve additional goals, which is expanded on further in the next section.

## Internal gas exchangers and superheaters

With traditional antiquated converter designs, gas exchangers and superheaters are all placed external to the converter with a labyrinth of ducting inter-connecting all the various equipment. The result is a costly plant with an overly complex layout and excessive process containment surface area where leaks will inevitably occur. Hot gases combined with rigid converter/ducting designs lead to very high stresses and subsequent material failure as the bed 1 and 2 outlet temperatures push the materials of construction to their maximum limits, resulting in $SO_2/SO_3$ leaks to the atmosphere (Fig. 5). Common leak points are converter/gas exchanger/superheater/ducting nozzles as well as ducting elbows and expansion joints. For these plants the perpetual struggle and related maintenance costs to control these leaks is an unfortunate reality.


*Fig. 5: Gas leak.*


*Fig. 6: Installation of internal gas exchanger.*

The design of the Chemetics radial flow converter includes an internal core where gas exchangers and superheaters can be placed (Figs 1 and 6). In a typical Chemetics converter there is enough space for multiple pieces of heat exchange equipment. The gas exchangers are designed so that the in and out flows align directly with the associated converter bed flow, all within the converter core. By situating gas exchangers internal to the converter, the process containment surface area of the plant is significantly reduced and all the potential leak points for the internal equipment are eliminated. This approach eliminates the gas exchanger and superheater shells, all ducting, insulation, and nozzles associated with the internal equipment. In essence, all the parts that cause the vast majority of the leaks are eliminated. An additional benefit from the elimination of major ducting runs is the reduction in system pressure drop.

Chemetics has successfully used internal gas exchangers since 1983, with over 30 installations. The one question that remained regarding this approach was the viability of replacing an internal gas exchanger that reaches end-of-life prior to the converter. For the replacement of an external gas exchanger the execution is well known and documented. For replacement of an internal gas exchanger the execution plan was developed by Chemetics long ago and is quite straightforward. The converters are designed specifically to allow this to occur. Fortunately, from 1983 until 2015 there was never a need to replace any of the Chemetics designed internal gas exchangers. It turns out that by eliminating the shell, insulation, ducting, and nozzles and associated stresses on the gas exchanger (as well as only installing equipment that cannot have acid dew point condensation within the converter core), this has extended the life of the units.

In 2015 the opportunity for such a replacement presented itself. A North American client with a sulphuric acid regeneration (SAR) plant and a Chemetics converter installed in 2006 needed to replace its internal hot gas heat exchanger (HHX). The plant process is somewhat unique in that combustion is enriched with oxygen. It was determined that the oxygen-enriched combustion products were attacking the HHX at its high metal temperature. The converter was in good shape and the decision was made to replace the internal HHX with a new unit with upgraded metallurgy.





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*Fig. 7: Top core duct assembly removal.*


*Fig. 8: Exposing top of internal HHX for removal.*


*Fig. 9: Removal of old HHX complete unit.*


*Fig. 10: New HHX prepared for installation as complete unit.*


*Fig. 11: Chemetics converter module delivery.*

Chemetics worked with the client to plan and execute the replacement project. The project involved removing the core duct assembly (Fig. 7) to expose the top of the HHX (Fig. 8). Baffle seal plates were removed and then the HHX was lifted and removed as a complete unit (Fig. 9). The reverse sequence was then executed to install the new HHX (Fig. 10). The project was a success and completed comfortably on schedule in three weeks, within a five-week overall shutdown. This replacement project demonstrated that with proper planning, the replacement of an internal gas exchanger is completely viable and straightforward.

## Modular converter assembly

The converter is by far the largest piece of equipment in a sulphuric acid plant, with some of the largest reaching 100 ft (30 m) high and over 66 ft (20 m) in diameter. Replacement projects can be complex and should be planned thoroughly and well in advance. The old converter must be demolished, and the new converter installed with minimum plant downtime and operational disruption. Replacement projects are much more challenging in every aspect, when compared to erecting a converter for a new plant build.

Replacing a converter with the older grid-and-post design can limit options regarding location and layout. Moving a fully assembled grid-and-post converter is nearly impossible, as all the internal components are loosely stacked and susceptible to shift. Typically, it is recommended that grid-and-post converters are assembled where they will remain and operate. Replacing with a grid-and-post converter in the location of an existing converter is rarely a viable option. The amount of outage time required to demolish the existing converter, assemble a new grid-and-post converter, and then tie in all the ducting would be excessive and impossible to justify for virtually any plant. For these reasons converters that are replaced with a grid-and-post design are most often planned for a new location. This is greatly dependent on whether there is available plot space. The benefit to a new location is that the required outage time is minimal as the new converter is assembled during plant operation, leaving only the ducting tie-in's to be completed during the outage. The downside is that a new foundation is always required, and ducting run length will increase along with pressure drop.

The modern Chemetics radial flow, all welded, stainless steel converter allows for a full spectrum of viable location/layout options. Due to its all stainless steel construction, the Chemetics converter will always be lighter than any stainless steel or carbon steel, brick-lined grid-and-post converter that is being replaced. This means that the existing foundation can be re-used if it is in decent condition. The other related benefit to this design is that it lends itself to a modular fabrication/assembly strategy. The converter can be delivered to site in modules on trucks (Fig. 11). The modules are sized to fit the shipping envelope and maximise the shop fabrication work while minimising the field work. The converter modules are typically 12 ft (3.7 m) high and are designed to combine in levels (Fig. 12). Each level can be thought of as a layer to a cake, with a converter often having 5-7 levels. Each level may consist of only two half-ring modules (Fig. 13) for smaller converters, or several pie-shaped modules (Fig. 12) for larger converters. The converter will be assembled in sequence, one level at a time, starting with the bottom. Each level is preassembled from the modules then lifted and fit as a complete piece (Fig. 14). The modules each contain some core and shell segments connected by baffle/grid and or head material, resulting in excellent stability for shipping and field handling/assembly (Fig. 15). This execution model allows for up to 85% of the overall converter welding and 90% of the fitting to be completed in a fabrication shop. The remaining site work requires a small crew size and will result in a high quality converter due to the dimensional accuracy of the modules. Maximising the shop fabrication component of the project maximises the quality control and minimises the schedule duration and risk.

**Fig. 12: Chemetics modular assembly of a level**

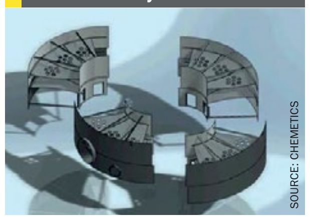



*Fig. 13: Two half ring modules per level for smaller converters.*







*Fig. 14 (above left): Complete level lifted into position. Fig. 15 (above right): Dimensionally stable module completed at chemetics fabrication facility.*


*Fig. 16: New Chemetics converter lifted for installation.*

Chemetics owns a state-of-the-art fabrication facility in Pickering, Ontario, Canada where converter modules and other process equipment are manufactured. The equipment is fabricated to the highest quality standards based on 60+ years of experience supplying the global sulphuric acid industry. Chemetics also regularly works with third party fabricators local to the clients' site, depending on the location, and to minimise shipping costs where appropriate. As a fabricator, Chemetics is able to work closely with third part fabricators to ensure they perform at the same high level of quality.

If the client chooses to install the new converter in a new location the modules will be assembled on the new foundation while the plant is operating, with new ducting tie-ins completed during the outage. This is the option with the shortest required outage (approximately two weeks).

The option that becomes available with the Chemetics modular approach is that the new converter can be placed in the location of the old converter. This is accomplished by assembling the converter on a grillage in a temporary location adjacent to the plant while in operation. The converter internals will also often be installed during this time prior to the outage. During the outage the old converter is demolished/removed, and the new converter is either slid or lifted into place. The sliding option is often chosen when there is a clear path of ground access. The lifting option (Fig. 16) is chosen when there is no sliding access and an appropriate crane is available. Due to the weight, the crane will lift from the grillage which would be designed accordingly. The grillage is permanent and will interface with the existing foundation. The final step is to complete the ducting tie-ins. The Chemetics converter can be designed with 360-degree freedom for nozzle locations, therefore ducting modifications are typically minimal. With proper planning this execution model can be completed during a reasonable and typical annual outage duration (approximately four weeks).

## Summary

Converter replacement projects can be more complex and challenging when compared to the supply of a new converter and plant. However, with this challenge there also comes the opportunity to realise various goals to upgrade an existing plant. Since the introduction of the modern radial flow, all welded, stainless steel converter this technology, Chemetics has designed and installed approximately 70 converters globally, including new plants and retrofits. Most of the retrofits have occurred in the past 15 years, as many of the world's sulphuric acid plants have begun to reach a critical age. Virtually all these converters were supplied with the Chemetics modular approach which has produced exceptional results. Chemetics has a proven track record and can support the client from concept to installation and commissioning.

As the converter in your plant approaches end-of-life, planning ahead and selecting a reputable technology vendor with significant converter retrofit experience is critical. The correct vendor can ensure a successful project that maximises return on investment, minimises disruption to operations, and positions the plant to meet all current and future performance goals.





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# Decreasing tail gas treating carbon intensity through solvent and catalyst swaps

Decreasing the carbon intensity of sulphur recovery is one of the many actions that operators can take to help meet their climate ambitions. It is also becoming increasingly rewarding financially because of the rising cost of carbon emissions. In this article, **G. Kidambi** of Shell Projects & Technology demonstrates the potential to cut the carbon intensity of tail gas treating units by more than 50% through swapping to the latest SCOT ULTRA amine solvent and catalyst technologies.

Demand for energy will continue to increase as growing global populations need more energy to support a decent quality of life. It is still technically possible for society to achieve the stretch goal of the Paris Agreement: to limit the global average temperature rise to 1.5°C above pre-industrial levels this century. However, this will require a rapid transition from an energy system that relies on fossil fuels to one that increasingly uses sustainable sources of energy, but even the most optimistic forecasts have fossil fuels continuing to play a crucial role for decades.

There are multiple opportunities to lower the carbon intensity of hydrocarbon processing facilities. Making the change to lower carbon intensity operations is the right thing to do and provides financial opportunities as the incentives for cutting emissions and the penalties for not doing so rise. The cost of carbon dioxide ($CO_2$) in the EU emissions trading scheme reached a record high of €89/t[1] on 8 December 2021 because carbon-intensive businesses are competing to buy enough permits to match their rising post-pandemic emissions.

In Powering Progress, its business strategy, Shell sets out to accelerate its transition into a net-zero emissions energy business by 2050, in step with society. To do so, Shell will reduce emissions related to its own operations. The company also sets out to reduce the emissions from the use of all energy products it sells, and capture, store or offset any remaining emissions.

Meeting sulphur emission regulations is imperative for a company's licence to operate but the process of removing sulphur from gas streams can be energy intensive. The Shell Claus off-gas treating (SCOT™) ULTRA process is one of many options for decreasing the carbon intensity of refining and gas processing that has been developed and is applied at Shell-operated facilities and offered to customers. The Shell Blue Hydrogen Process and Shell Renewable Refining Process are two other refinery decarbonisation options.

The sulphur recovery section of a refinery or gas processing facility is built to protect a company's licence to operate rather than to generate revenue, as the sulphur market price is volatile and the cash generation from elemental sulphur is small in comparison to the main revenue streams. Consequently, the success of the sulphur recovery technology and the design used is measured in terms of capital expenditure, operating and carbon costs, flexibility, and robustness.

The primary focus of this article is on the potential to reduce the carbon intensity of tail-gas treating units through changing to SCOT ULTRA technology: a new solvent and a new-generation low-temperature catalyst. (The solvent and the catalyst can be swapped together or independently.) A secondary climate-related benefit of the solvent swap it that enables these units to operate with greater resilience to upsets and at higher ambient temperatures. These are important benefits for systems running close to their limits or in regions where more frequent and intense weather extremes, driven by climate change, are placing high demands on cooling systems.

The expected benefits of SCOT ULTRA technology were widely reported when it was launched in 2018. The technology has now been operating in multiple facilities and its advantages are proven, including its ability to:

- lower operational expenditure and carbon footprint, and/or increase capacity;
- operate the tail gas unit at lower temperature;
- provide increased resilience to upsets;
- offer greater flexibility to handle changing crude slates and upstream gas composition;
- decrease or avoid capital expenditure for greenfield developments.

## SCOT process overview

Thermodynamics limit the sulphur recovery from modified Claus sulphur recovery units (SRUs) to 96-98%. Therefore, to meet current sulphur oxide (SOx) emission regulations, a downstream tail gas treating unit, such as a SCOT unit, is necessary to achieve greater than 99.9% recovery.

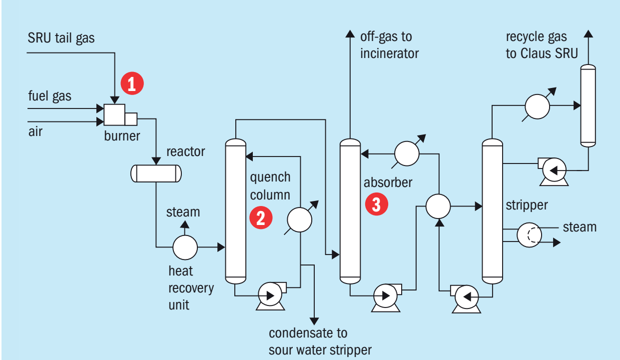
The SCOT process uses a three-step approach to enable efficient and deep recovery of the residual sulphur species in the tail-gas stream.





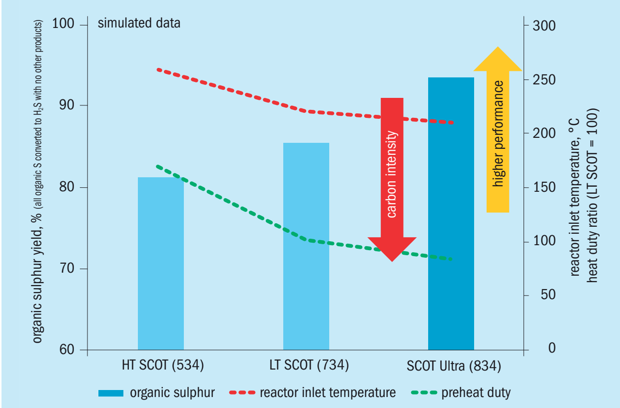


Fig. 1: **SCOT process overview**




Source: Shell Catalysts & Technologies

Fig. 2: **Catalyst swap for lower carbon density**




Source: Shell Catalysts & Technologies

SRU tail gas is preheated using a line burner or steam reheater (1, Fig. 1). Then a catalyst-based reduction reactor section converts the sulphur components of the gas (sulphur dioxide ($SO_2$); SOx; carbonyl sulphide; and carbon disulphide) into hydrogen sulphide ($H_2S$).

The gas is then cooled in in two steps: first in an (optional) heat-recovery exchanger, which produces steam, and then in a direct contact quench column (2). Claus reactions generate a significant quantity of water that is bled from the quench column to aid the performance of amine section (3). Here an aqueous amine solvent selectively captures and recycles $H_2S$ from the cooled gas to the front end of the SRU. The remaining sulphur species in the gas are incinerated to $SO_2$.

A Claus-based SRU is typically a net energy exporter at an operating site and the thermal oxidiser is its only major energy-consuming component. However, SCOT and alternative amine-based tail-gas treating units are energy intensive, which creates an opportunity to use new technologies to reduce operating costs and carbon emissions. The SCOT catalyst needs to be heated for the effective conversion of sulphur species to $H_2S$; the gas from the reactor must then be cooled; and then the amine must be circulated and regenerated to produce an $H_2S$-rich gas stream, all of which consume energy and create emissions.

## SCOT ULTRA for lower carbon intensity

SCOT technology has evolved significantly since it was first developed in the 1970s. Its latest evolution, SCOT ULTRA, which is essentially a solvent and a catalyst swap, though the swaps can be beneficially applied independently, has the potential to cut carbon intensity by over 50% compared with earlier designs.

The original SCOT design used a conventional secondary amine (diisopropylamine: DIPA) or a tertiary amine (methyl diethanolamine: MDEA) for the amine absorption section. Later, acid-aided regeneration (AAR) (formulated) MDEA was used to lower the energy consumption in the amine reboiler while meeting a low $SO_2$ specification in the flue gas (Low Sulphur or LS SCOT technology).

The original catalysts had to be heated to above 260°C. New catalysts that operated at about 220°C and lower were then introduced (low-temperature or LT SCOT technology). The latest 934 catalyst is effective at an inlet temperature of 200°C while meeting the demanding performance requirements through its higher hydrolysis and hydrogenation capacity. Incorporating the new catalyst in the SCOT ULTRA technology helps to reduce carbon intensity and provide potential operational savings of hundreds of thousands of dollars a year, depending on the temperature delta and unit size, by reducing fuel gas consumption and enabling the use of indirect heating methods.

In addition, Huntsman has worked with Shell to develop JEFFTREAT® ULTRA, a temperature-resilient, sterically hindered amine solvent that is used in the SCOT ULTRA process to enable lower circulation rates for lower energy demand and superior $H_2S$ absorption performance. JEFFTREAT ULTRA solvent outperforms AAR (formulated) MDEA by providing deeper $H_2S$ removal (lower $SO_2$ emissions), more capacity, the ability to "slip" more $CO_2$ and better upset ($H_2S$ spike) resilience.

As the upgrade to SCOT ULTRA technology is essentially a catalyst and solvent swap, the opportunity to cut carbon intensity by 50% comes with minimal capital expenditure.





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## Lower carbon intensity; higher performance catalyst

A simulation using proprietary Shell models demonstrates a 50% lower carbon intensity and about a 15% higher yield at a 50°C lower temperature for SCOT ULTRA technology with 834 catalyst compared with the 534 conventional high-temperature (HT) SCOT catalyst (Fig. 2).

The modelled scenario is a Middle Eastern gas plant with a high ambient temperature, a lean acid gas feed to the SRU (54 mol-% $H_2S$, 34 mol-% $CO_2$, trace hydrocarbons and the rest water), a 250-t/d sulphur capacity and the need to achieve 99.9% sulphur recovery.

## Higher selectivity and lower circulation rate solvent

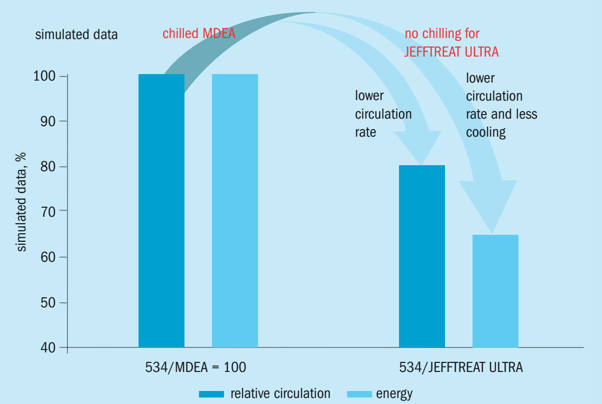
In the same scenario, swapping MDEA for JEFFTREAT ULTRA solvent lowers the circulation rate and thus energy requirement (Fig. 3). In addition, there is no need to chill the new solvent, even in a Middle East setting, which further decreases the energy demand and consequently lowers the $CO_2$ footprint.

## Catalyst and solvent integration for greater benefits

The SCOT ULTRA process is more than the development and use of a high-performance catalyst and a high-selectivity solvent; it is the integration of these elements based on expert knowledge and extensive operational experience. Although solvent and catalyst swaps can be made independently, applying them together, with proper integration, brings a greater benefit than the sum of each part. For example, better catalyst performance works alongside JEFFTREAT ULTRA solvent's higher absorption capability to lower solvent circulation rates by 25–55% compared with AAR (formulated) MDEA, which leads to lower operating costs and carbon intensity.

The integration decreases the overall carbon footprint by 54% (Fig. 4) compared with using MDEA. This comes from the lower reboiler duty and reactor operating temperature. Lower carbon emissions provide financial benefits through avoiding carbon levies or attracting emission reduction incentives. At a carbon cost of \$25–50/t $CO_2$, simulations based on a catalyst and solvent swap in a 250–500-t/d brownfield facility show a return on investment for SCOT ULTRA of just

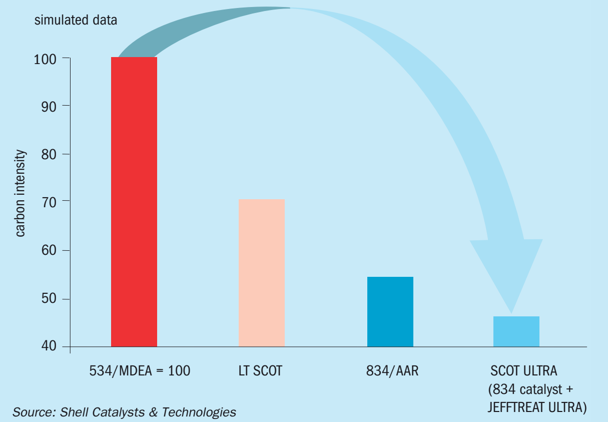
Fig. 3: Solvent swap for lower energy requirements




To meet the specification, MDEA requires a small amount of chilling owing to high organic sulphur. JEFFTREAT ULTRA equires no chilling.

*Source: Shell Catalysts & Technologies*

Fig. 4: Carbon intensity reduction




*Source: Shell Catalysts & Technologies*

Table 1: Three US refineries operating SCOT ULTRA technology

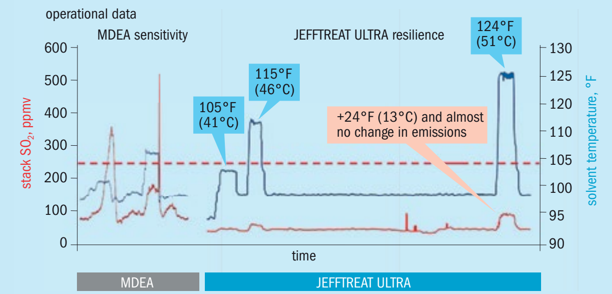
| Refinery 1 | Refinery 2 | Refinery 3 |
|---|---|---|
| 168 t/d sulphur | 168 t/d sulphur | 117 t/d sulphur; lean acid gas |
| Tested up to a lean solvent temperature of 62°C | – | Tested up to a lean solvent temperature of 51°C |
| Operating since 2018 | Operating since 2019 | Operating since 2020 |

*Source: Shell Catalysts & Technologies*



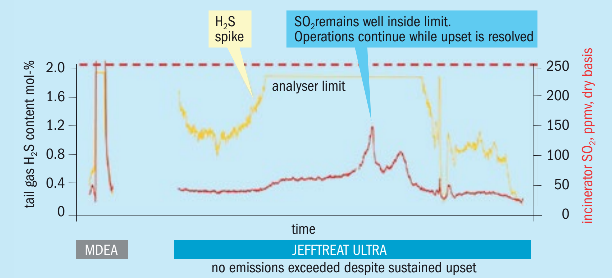


Fig. 5: Temperature resilience before and after a solvent swap




*Source: Shell Catalysts & Technologies*

Fig. 6: Unit resilience before and after a solvent swap




*Source: Shell Catalysts & Technologies*

one year. And that is solely from lower carbon costs without considering the additional benefits of fewer shutdowns from greater resilience to upsets.

## Commercial performance

SCOT ULTRA technology has been operating at multiple facilities for a significant time (Table 1) and the simulations are now supported with operational information.

The following example demonstrates the operational robustness against high temperatures and upsets for a SCOT unit in a US refinery that swapped MDEA for JEFFTREAT ULTRA technology. The SRU feed has high (35 vol-%) $CO_2$ concentrations; the Claus unit has a lower than typical sulphur recovery that places a high load on its SCOT unit; the unit operates with lower than typical steam rates; and emissions are base loaded by the degasser pit vent, which is routed to the incinerator.

Fig. 5 shows the unit's sulphur emissions (red lines) before and after the solvent swap, and the solvent temperature (blue lines). With MDEA, a modest 3°C (5°F) increase in the solvent temperature caused the $SO_2$ limits to be exceeded, whereas tests using JEFFTREAT ULTRA solvent and a 13°C (24°F) increase in solvent temperature showed a minimal change in the $SO_2$ concentration. Overall stack $SO_2$ decreased from 60-80 ppmv to circa 40 ppmv.

The carbon intensity benefits of reducing or eliminating the need to chill the solvent are discussed above; the overall 54% decrease in carbon intensity is related to this and the reduced circulation rate, reboiler duty and reactor temperature. Circulation rates were lowered by 30% compared with MDEA without compromising absorption capacity.

Over the last few years, great demands have been placed on shared refinery cooling systems during extreme weather events, which are becoming more frequent and of higher intensity because of climate change. Taking the SCOT unit out of the cooling equation through a simple solvent swap helps to strengthen the resilience of the wider system.

Fig. 6 shows the how the same unit performed before and after a solvent swap with similar scale $H_2S$ spikes (the yellow lines, which go beyond the analyser limit in both cases). The red lines show the $SO_2$ values. With MDEA, the $SO_2$ limits were quickly exceeded, so the operator was forced to respond by shutting down the unit until the upset could be resolved. With JEFFTREAT ULTRA technology, despite the longer duration of the $H_2S$ spike, the $SO_2$ emissions remained well inside limits and gave the refiner time to resolve the issue without reducing throughput or shutting the unit down.

This operational information is from a solvent swap at one refinery. Two other commercial operations show similar results. Swapping the catalyst would lead to further advantages as highlighted above.

## Conclusions

In a cash-constrained, decarbonising world, SCOT ULTRA is one of many Shell technologies that can help to reduce the carbon intensity of refineries and gas processing facilities. In addition to helping to meet stringent SOx specifications while offering lower operating costs and thus lower carbon emissions, as a solvent and catalyst swap, it is a low capital expenditure solution.

The technology enables the reduction reactor section of a SCOT unit to operate at a lower temperature (less energy for heating) and the absorber section to operate at a higher temperature and capacity (less energy for cooling and circulation). This helps to meet multiple needs, including greater resilience to upsets and cooling challenges, and the flexibility to handle turndowns and changing crude slates and upstream gas composition. Taking the SCOT unit out of the equation through a simple solvent swap helps to strengthen the resilience of the wider system, despite the new demands on cooling systems because of climate extremes.

Commercial performance data prove the ability of a SCOT ULTRA solvent swap to increase resilience to upsets and temperature and demonstrate the potential for decreasing carbon intensity.

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# A novel monitoring and advisory system for SRUs

**N. A. Hatcher, D. R. Jensen,** and **P. L. Ott** of Optimized Gas Treating Inc. provide a technology overview of ProBot™ – a unit monitoring system developed by OGT to digitalise the sulphur processing assets in a facility in a manner that facilitates knowledge retention, rapid optimisation, and plant troubleshooting. ProBot™ has been built to allow rapid access to a virtual plant platform that provides advice, training and, monitoring to enable more efficient, safe, reliable, and environmentally friendly plant operations.

> ***For over a thousand generations, the Jedi Knights were the guardians of peace and justice in the Old Republic. Before the dark times, before the Empire…"***
> Obi-Wan / Ben Kenobi, Star Wars Episode IV

> ***'The world has moved on', we say.., we've always said. But it's moving on faster now. Something has happened to time."*** Stephen King, The Dark Tower Series

Before Covid, did Stephen King and George Lucas have the prescience to predict the mess that Covid-19 would leave on the world? Probably not, but the world is definitely "moving on" and was headed that direction even before the pandemic. Like it or not, reality has become that in many aspects of life, humans are slowly and steadily being replaced by their own ingenuity, reduced to software algorithms. Self-driving cars, drone mail package delivery, artificial intelligence (A.I.), and machine learning are all examples of these amazing feats of human ingenuity.

In due time, a self-driving car may be trained not to follow the crooked white stripe that the drunken highway worker painted into the ditch. Maybe someday Microsoft Windows or iOS operating systems will not require rebooting on the fly to install updates. These are some of the hurdles that digitalisation still has to overcome – maintenance and updates to the updates. Who, or perhaps better "what" is going to supervise the updates?

The stakes go up considering the risks associated with process plant operations, where toxic, flammable and energy-laden fluids are handled. Sulphur processing units (amine, SWS, sulphur recovery, tail gas cleanup units) are no exception here.

Remotely operated plants are becoming more common. As plants and processes become more efficiently operated and economic pressures to stay in business increase, staffing reductions in the oil and gas industry have become more of a reality leading inevitably to a pronounced lack of knowledge capture and retention. This effect could be likened to corporate version of Alzheimer's disease.

> ***Time's the thief of memory"***
> Stephen King, The Dark Tower Series

The next generation can only begin learning where the previous generation left off. When know-how is lost, mistakes that could have easily been avoided are instead repeated. Digitalisation of plant assets, in a manner that leverages the training potential that an accurate model can provide for process plant operations, is a significant step in the right direction.

## ProBot™ technology overview

The ProBot™ unit monitoring system was developed by OGT to digitalise the sulphur processing assets in a facility in a manner that facilitates knowledge retention, rapid optimisation and plant troubleshooting. As opposed to a reduced-order model that serves as a real time "digital twin" of a process plant, ProBot is a monitoring and advisory system interface that instead can be used to:

- automate the transfer of distributed control system (DCS) plant and laboratory data into the highly accurate and well respected ProTreat® and SulphurPro® steady-state rate-based simulators that are driven in the background;
- audit plant data and provide material and energy balance (MEB) feedback about the quality of the plant instrumentation readings;
- compare predicted (simulated) with measured performance to know better how much accuracy to expect from the process model;
- provide feedback on the areas where known corrosion and mechanical integrity are problematic, and;
- provide expert process advice on the operations of amine, sulphur recovery units (SRU), tail gas unit (TGU), and sour water stripper (SWS) systems.

ProBot was not designed to replace experienced and knowledgeable engineers and operators. It was built with the intention to allow rapid access to a Virtual Plant platform that provides advice, training and, monitoring to enable more efficient, safe, reliable, and environmentally friendly plant operations.

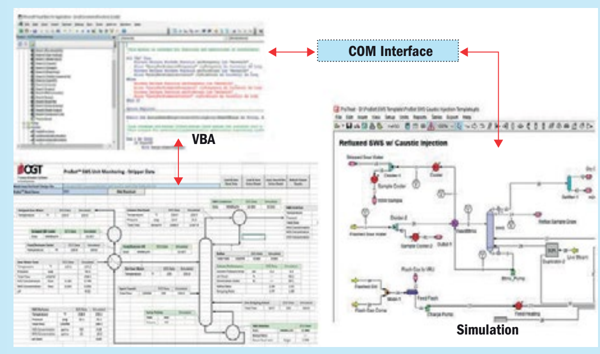
The ProBot system is hosted within Microsoft Excel to allow ready transfer and interface of data between a DCS data historian and the components of ProBot. Visual Basic for Applications (VBA) and proprietary OGT .dll libaries are used to communicate and exchange data between the virtual plant models (i.e. ProTreat® or SulphurPro®), the visual spreadsheet-







Fig. 1: **ProBot™ interface**




*Source: Optimized Gas Treating Inc.*

interface, and the Process Advice Modules (PAM).

Fig. 1 shows the ProBot™ interface.

A ProBot module has been developed for each major type of sulphur processing unit (Amine, SWS, Claus, TGU).

By "checking out" the current model of the process, "What-If" scenarios can be constructed to allow optimisation strategies to be explored and tested on the computer before trying them out in the field. Additionally, training exercises can be more easily constructed with virtual plant models. With these features, corporate Alzheimer's can be effectively engineered out.

The ProBot Beta Version is currently in a field-testing stage at several operating facilities. In the rest of this article, several examples of the benefits that have already been seen at these trials are highlighted.

## Claus SRU ProBot benefits

A refinery Claus SRU system similar to that depicted in Fig. 2 was experiencing intermittent high pressure at the SRU front-end as well as apparent loss of sulphur conversion as evidenced by elevated temperature rise in the TGU Hydrogenation Reactor and increased recycle acid gas flow. Concurrent with these problems, operators reported periodic sulphur plugging in several of the sulphur rundown lines that required manual removal by rodding out.

The partial view of the ProBot setup for this Claus unit is shown in Fig. 3. A summary of the computed versus measured performance (see Fig. 4) showed that:

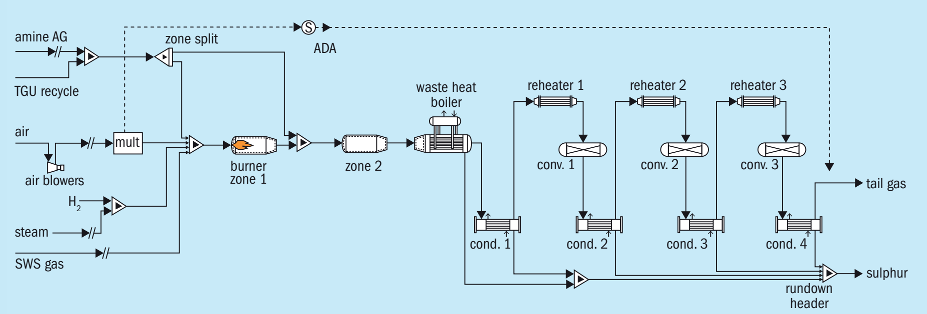
- conversion in the first Claus converter had declined;
- steam consumption in the first reheater was greater than expected;
- boiler feedwater makeup was higher than expected while steam production rate was considerably less than expected in the first condenser upstream (shown later).

With this feedback from ProBot to supplement the operator reports of rod-out frequency increasing in the sulphur rundown header, plant personnel had more confidence that an exchanger upstream was leaking. A radioactive dye tracer test confirmed that the waste heat boiler (WHB) was not leaking while the first sulphur condenser was leaking several US gallons per minute of boiler feedwater into the process. Plant operations were able to carry on with an online configuration change. This change was initially tested and proven using the SulphurPro® model that was checked out from ProBot, thereby avoiding an unplanned outage.

An additional side benefit from this ProBot trial was identifying several potential safety concerns in the thermal reaction section of the SRU. The ProBot metrics and advice dashboard for the system is shown in Fig. 4.

The simulated temperatures in both reaction furnace zones were considerably higher than the plant measurements, which led ProBot to advise calibration of the field instruments. In the front zone, the simulated temperature exceeded the maximum safe operating temperature recommended by the refractory vendor for this installation. So, the ProBot advisor suggested reducing the amount of acid gas bypass to the back zone. The corrected amount of bypass flow that was

Fig. 2: **Refinery Claus SRU configuration**




*Source: Optimized Gas Treating Inc.*







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chosen was initially determined by the plant engineer re-running the SulphurPro background model.

The back zone furnace temperature showed even more deviation between the optical pyrometer field indication and the calculated figure from ProBot. Further investigation by an OGT consultant found that the pyrometer was installed with a nearly four feet long view port so that the pyrometer could be accessed from the platform above the furnace. A pyrometer indicates the integrated average temperature across the pyrometer's view path. Unfortunately, in this case that view path includes a portion the nitrogen-purged nozzle, which will be much colder than the furnace refractory. This section of relatively cold temperature significantly skews the indicated temperature lower than the actual temperature in the second zone.

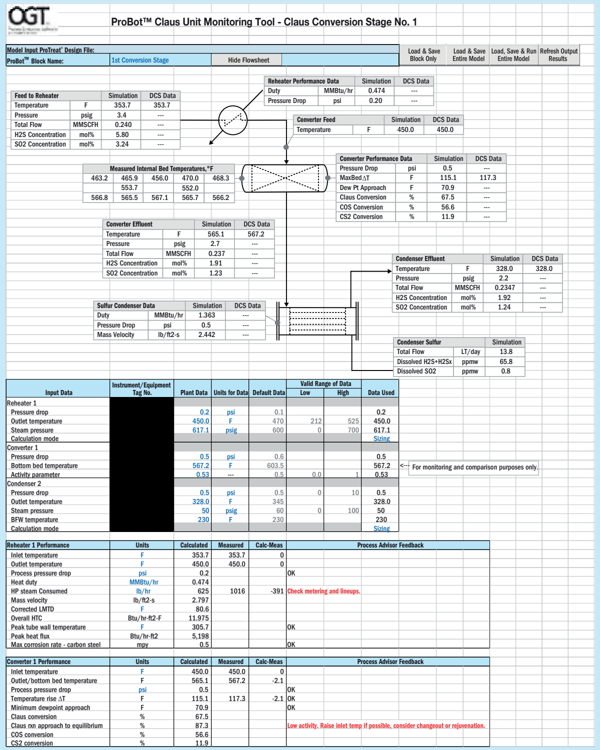
Fig. 4 also shows a large discrepancy between metered boiler feed water consumption and the virtual plant model predictions. Because SulphurPro includes a rigorous heat transfer rate-based model for SRU process exchangers, these comparisons can be readily made as a function of unit throughput and operational conditions. Step changes in fouling resistance will manifest into deviations between the model predictions and plant operating data allowing for earlier detection of process plant equipment issues. Sulphur plant exchangers may be readily flipped from sizing mode to rating mode to assess how the plant should be behaving versus actual operations.

The ProBot framework also includes access to SulphurPro's sulphidation corrosion rate predictions. SulphurPro incorporates several different models for sulphidation corrosion for both carbon steel and several upgraded metallurgies based upon several variations of the Couper-Gorman curves and includes recent data from Alberta Sulphur Research, Ltd. (ASRL)[1]. Fig. 4 shows computed maximum tube wall corrosion rates of 7.4 mpy in the waste heat boiler and 0.5 mpy in the thermal condenser. These sorts of predictions can be particularly useful in oxygen-enriched sulphur plant operations where temperatures and $H_2S$ partial pressures are elevated over air-only operations.

## Amine unit benefits

The successful integration of several features has been realised at an amine-based sour gas treating facility. The plant now has access to real-time corrosion rate predictions from the ProTreat® corrosion coupon unit operations which are updated each time the ProBot tool is refreshed. This permits comparisons over time with field pipe wall thickness measurements as well as inline installed corrosion probes and coupons. Fig. 5 shows the output for one point in time flagging several areas for attention. Surprisingly, the problems were identified on the lean amine circuit versus the more heavily loaded rich amine side.

Fig. 3: **ProBot™ elements for 1st Claus catalytic stage**




*Source: Optimized Gas Treating Inc.*

Fig. 4: **ProBot™ thermal reactor metrics**

| Reaction Furnace Monitoring | Units | Calculated | Measured | Calc-Meas | Process Advisor Feedback |
|---|---|---|---|---|---|
| Zone 1 Temperature | F | 2987 | 2520 | 468 | Calibrate TI Temperature too high - consider reducing acid gas bypass |
| Zone 2 Temperature | F | 2495 | 1690 | 805 | Calibrate TI Temperature ok |
| Effluent NH3 | ppmv | 0.6 | ---- | | NH3 destruction ok |
| % of Total H2S to Burner | | 55.4 | | | OK |

Sulfur Production For Stage

| Stage | StreamID | Flowrate | Units | % Recovered | Cumulative % |
|---|---|---|---|---|---|
| Thermal | 39 | 19.4 | LT/day | 47.32 | 47.32 |

| WHB Performance | Units | Calculated | Measured | Calc-Meas | Process Advisor Feedback |
|---|---|---|---|---|---|
| Process Outlet Temperature | F | 760.9 | 760.9 | 0 | High tube wall temperature. Carbon steel corrosion rates could be excessive |
| Process Pressure Drop | psi | 0.3 | | | OK |
| Heat Duty | MMBtu/hr | 12.420 | | | |
| Steam Produced | lb/hr | 16,392 | 11,652 | 4,741 | Check metering and lineups. |
| Mass Velocity | lb/ft2-s | 1.172 | | | |
| Corrected LMTD | F | 863.8 | | | |
| Overall HTC | Btu/hr-ft2-F | 8.944 | | | |
| Peak Tube Wall Temperature | F | 529.3 | | | OK |
| Peak Heat Flux | Btu/hr-ft2 | 20,746 | | | OK |
| Max Corrosion Rate - Carbon Steel | mpy | 7.4 | | | OK |

*Source: Optimized Gas Treating Inc.*





Fig. 5: **Virtual corrosion coupon output**

Corrosion Coupon Virtual Monitoring Results
Max permissible corrosion rate 10 mpy
Target minimum service life 20 years

| Service | Coupon Name | Piping Material | Pipe ID | Velocity | Calculated Corrosion Rates, mpy | | | | Service Life, years | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | in | ft_s | Straight | 90°Elbow | 3-D Bend | Welds | Straight | 90°Elbow | 3-D Bend | Welds |
| Cold lean amine | Corrosion Coupon-1 | Carbon Steel | 23.250 | 4.1 | 5.1 | 6.2 | 5.5 | 6.5 | 24.6 | 20.2 | 22.8 | 19.3 |
| Absorber bottoms | Corrosion Coupon-2 | Carbon Steel | 29.250 | 2.7 | 5.2 | 6.4 | 5.6 | 6.8 | 24.2 | 19.5 | 22.2 | 18.4 |
| Hot rich amine | Corrosion Coupon-3 | Carbon Steel | 29.250 | 10.6 | | | | | | | | |
| Hot lean amine | Corrosion Coupon-4 | Carbon Steel | 23.250 | 4.6 | 52.0 | 55.2 | 53.3 | 56.3 | 2.4 | 2.3 | 2.3 | 2.2 |
| Intermediate lean amine | Corrosion Coupon-5 | Carbon Steel | 23.250 | 4.5 | 20.2 | 21.3 | 20.7 | 21.8 | 6.2 | 5.9 | 6.1 | 5.7 |

*Source: Optimized Gas Treating Inc.*

Fig. 6: **Real amine sample (left) vs virtual sample advisor**


**Adviser feedback on sample visual**
*Hydrocarbon levels appear to be low.*
*High levels of sodium may be present and/or degradation products.*

*Source: Optimized Gas Treating Inc.*

## Plant data validation

The accuracy of a digital twin and making sound operational decisions depend heavily upon having accurate plant instrumentation readings and laboratory analyses. A key feature of the ProBot architecture is that validation checks are provided in the right areas on the plant data itself.

In terms of the amine analysis, validation by a solution charge balance is provided. Additionally, a visual amine hygiene feature is available. The visual advisor is intended for day-to-day checks by operations where an actual sample is used to calibrate the "virtual" sample colour and clarity until a match is made. The advisor provides feedback on the levels of contaminants that may be present in solution and suggests possible actions that may need to be taken. An example is provided in Fig. 6.

Rich amine loading measurements are compared to an energy balance by methodology similar to that furnished by Oberbroekling et al[2]. When a single amine contactor is tied to a single regeneration circuit, the rich amine loading can be also cross-checked versus the material balance on the acid gas flow. Calculated regenerator energy reboiler duty, which is determined by energy balance, is compared to the field measured value which can be useful to identify plant instrumentation issues. It is surprising to find out just how many ways there are to meter steam flow to a reboiler incorrectly.

Table 1: **Heat exchanger utilisation**

**Heat exchanger duties**

| Service | Units | Current | Design | Design limit, % |
|---|---|---|---|---|
| Lean/rich exchanger | MMBtu/hr | [redacted] | | 79.5 |
| Lean amine cooler | MMBtu/hr | | | 96.1 |
| Lean amine trim cooler | MMBtu/hr | | | 88.8 |
| Refrigerator condenser | MMBtu/hr | | | 107.3 |
| Refrigerator reboiler | MMBtu/hr | | | 99.9 |

*Source: Optimized Gas Treating Inc.*

The ProBot amine system also includes several other useful economics-related metrics that can be tied into plant economics LP models, or used to justify improvement projects. Because amine units along with other sulphur processing units tend to be viewed as "utilities" to keep the hydrocarbon production units in operation, they often receive little maintenance attention until it is too late. The cost metrics provide some useful data to help plant operators receive attention that these units deserve. Metrics that are provided include:

- amine inventory estimation, amine losses, and comparison of losses vs. first quartile performance benchmark from data collected by the industry Amine Best Practices Group (ABPG)[3];
- electrical power consumption for major process motors in pumps and air coolers;
- water makeup, cooling water, and steam utility cost.

In terms of asset utilisation, the major amine unit process equipment operations are compared to design data, where available, to provide important data on potential unit bottlenecks and optimisation areas. As an example, Table 1 provides sample information on the heat exchanger utilisation in a primary amine system.

## Commercial status

OGT is presently collecting feedback from several operators on the current components that are in the ProBot monitoring system. A target release for the finished suite is midyear 2022. Several licensing options will be available. With the availability of a complete set of plant data that is ready to snapshot, troubleshooting support and optimisation by OGT consultants can rapidly diagnose problems. As soon as the ProBot snapshot is turned over, the troubleshooting or optimisation effort can begin.

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