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Number 384 September | October 2019

# SULPHUR

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## Sulphur + Sulphuric Acid conference, Houston, Texas

## Sour gas projects

## Sustainability in sulphur recovery

## Sulphur enhanced fertilizers

CONTENTS



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SEPTEMBER-OCTOBER 2019

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34
35



**Cover:** *A shelf full of cowboy boots iStockPhoto.com/Iryna Novosyolova*

**North American phosphates**

Still a major slice of sulphur demand.

**Sulphur enhanced urea**

Combining nutrients for added crop effectiveness.

**Read this issue online at: www.sulphurmagazine.com**

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NUMBER 384 SEPTEMBER | OCTOBER 2019

## CONTENTS



## REGULARS



CONTENTS
What's in issue 384

COVER FEATURE 1
Sulphur + Sulphuric Acid conference, Houston, Texas

COVER FEATURE 2
Sour gas projects

COVER FEATURE 3
Sustainability in sulphur recovery

COVER FEATURE 4
Sulphur enhanced fertilizers

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# Tackling $SO_2$ emissions


Since we became aware of the problems that it can cause, during the late 1980s, the world has made great strides in tackling emissions of sulphur dioxide from burning sulphur-containing fuels and other sources. In doing so, the modern sulphur industry as we know it has been created, removing sulphur at source from oil and refineries and natural gas at gas plants, and converting $SO_2$-rich off-gas from smelters into sulphuric acid. And as we become more aware of the damage to health that even relatively low levels of $SO_2$ can cause, so the pressure to do more to tackle this continues. At the end of this year, permitted sulphur levels in marine fuels will fall from 3.5% to 0.5%, unless a ship is fitted with an $SO_2$ scrubbing system.

Marine fuel emissions represent around 5-10% of man-made $SO_2$ emissions, and this will help tackle a major slice of that, in so doing adding at least a couple of million more tonnes of sulphur per year to current output as refineries start to process the bottom of the barrel fractions that they have previously been able to leave largely unprocessed. But satellite imaging is also allowing us to get a much clearer picture of sulphur dioxide emissions and where they are coming from, especially the NASA OMI satellite, which since 2004 has been monitoring and mapping global emissions of $SO_2$. A report published this August by Greenpeace takes data from that satellite to map, measure and rank $SO_2$ emissions 'hotspots', and it makes for interesting reading.

One of the significant findings is that, while volcanoes and other natural sources make up 40% of global $SO_2$ emissions, the remaining 60% come from man-made sources. Coal-fired power stations represent 31%, the oil and gas industry 19%, and metal smelters 10%. Over the time that the satellite has been operational, the United States and China have both made great strides in reduction, with $SO_2$ emissions falling by around 85% in both cases, due to more stringent environmental regulation and less use of coal-fired power or the installation of flue gas desulphurisation (FGD) systems. India, conversely, has now slipped into first place, almost doubling its emissions as its use of untreated coal-fired power increases. The largest single emissions source is the Norilsk Nickel smelter in Russia, which emitted 1.9 million tonnes of $SO_2$ in 2018.

> "The largest single emissions source is the Norilsk Nickel smelter in Russia."

Steps are under way to tackle these emissions in some cases – Chile is in the process of cleaning up many of its copper smelters, and a plan to fit abatement technology to Norilsk is due in the next few years. The IMO regulations on marine fuels will, as discussed previously, also make significant inroads into emissions. But the report also highlights how far there still is to go and – for the sulphur industry – it also indicates how much extra sulphur or sulphuric acid might be expected to be recovered from some of these sources. The report's figure for $SO_2$ emissions just from identifiable 'hotspots' is around 30 million tonnes, equivalent to 15 million t/a of sulphur or 45 million t/a of sulphuric acid. Now, while half of this comes from coal-fired power stations, which are likely to use FGD and produce gypsum or other inert sulphates such as ammonium sulphate, the oil and gas emissions are likely to generate recoverable sulphur, and the smelter emissions will – for the most part – be converted to sulphuric acid.

This is not a given – it depends upon the location of the site. Norilsk for example had originally planned to convert all of the 1.5-1.7 million t/a of sulphur dioxide that its new scrubbing project will generate into elemental sulphur, producing up to 850,000 t/a of sulphur. However, the remote nature of the site means that most of this would probably end up being poured to block, and the new configuration, which is expected to come into operation in 2023, will instead convert most of the $SO_2$ into 5 million t/a of gypsum, and only generate around 280,000 t/a of elemental sulphur. Nevertheless, it means that even abatement from existing sites – as environmental regulations tighten even in some of the remoter parts of the world – could produce up to 3 million t/a of sulphur and 15 million t/a of sulphuric acid over the coming years, even before new installations are taken into account. ■

*Richard Hands, Editor*







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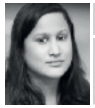
# Price trends



## MARKET INSIGHT

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

### SULPHUR

The global downturn in sulphur pricing has continued through 2019 into September, with expectations for the soft sentiment to remain rife until at least the end of the year. Major buyers appear covered through to the end of the month. The main market bear remains the downstream processed phosphates market, with lower prices plaguing sulphur consuming regions. The ongoing DAP production cuts in China are eroding market sentiment and adding to downward pressure in the global sulphur spot market. Upcoming fourth quarter contract negotiations will provide guidance on market direction, with decreases expected and likely across all regions.

Middle East producers posted prices at decreases for August and September with no upside to the market anticipated in the short term. Buyer pressure and low demand underpinned producer pricing. In Kuwait, KPC set its September price at $65/t f.o.b. Shuaiba – a drop of $10/t on the previous month. State-owned Muntajat announced its September Qatar Sulphur Price (QSP) at $65/t f.o.b., an $8/t drop on August, representing a three year low – a level not seen since mid-2016. The producer's monthly tender for 35,000 tonnes for August was heard scrapped for the third consecutive time. Meanwhile in the UAE ADNOC set its September monthly price at $68/t f.o.b. Ruwais for shipments to the Indian market – down by $10/t on the previous month. This represents the lowest monthly price set by the producer, dropping below the previous low of $70/t f.o.b. set in August 2016.

Fourth quarter contract discussions are expected to unfold during September, with decreases widely anticipated due to the significant drop in pricing in the last few months. The exception to this may be ADNOC. The producer recently its reduced third quarter contract prices with traders and for Moroccan shipments by $21-22/t – this may lead to either a rollover for the fourth quarter or a marginal decrease.

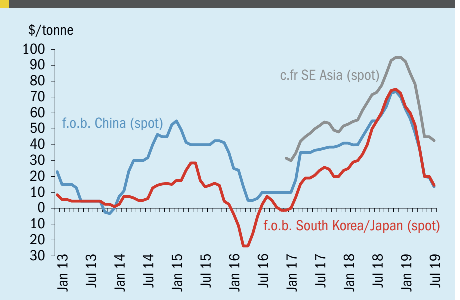
The supply outlook for the Middle East remains strong, with several projects set to boost output significantly and lead to increased export availability from the region. One of the main projects impacting supply is the Clean Fuels Project in Kuwait, this is now expected to come online during the first half of 2020. Production from KPC is eventually expected to increase to close to 3 million tonnes once the project reaches capacity. The long delayed Barzan project in Qatar is due to start up during 2020, with the two phased project set to add up to around 850,000 t/a of sulphur capacity.

Lacklustre demand in China continues to plague the market. Sulphur stocks at major ports have been climbing – breaching the 2 million tonne level at the end of August, signalling slow demand. Major DAP producers have cut production by 40% in China, leading to a dip in sulphur consumption, with the potential for this to be maintained through to the end of the year. If low processed phosphate operating rates remain, sulphur consumption in China could see a drop of over 1.7 million tonnes during the second half of the year. Spot prices in China dipped to $60-84/t c.fr at the end of August, down by 60% on the high end from the start of the year. On the import front, January-July 2019 trade data reflects a 7% uptick on a year earlier at 7.1 million tonnes. This rise is likely due to the growth in supply from the Middle East under contract. The Middle East remains the largest regional supplier for China, representing around 53% of total imports. The US-led sanctions are understood to have stimulated Iranian sulphur to China, becoming a leading destination for suppliers and traders. US sulphur trade to China has been negatively impacted by the 10% tariff on sulphur on the back of the US-China trade dispute. So far this year there has been a 59% drop to just 58,000 tonnes.

In Africa, a major potential growth market for sulphur, Moroccan demand is believed covered in the short term following recent purchases. The next round of spot for phosphates producer OCP is expected in the fourth quarter. According to Argus estimates, sulphur arrivals at the port of Jorf Lasfar are up 12% year on year at 3.1 million tonnes. Shipments of both sulphur and sulphuric acid to Morocco continue to be a bright spot for trade. However, the global downturn in sulphur prices and the challenges in the phosphates market is limiting price potential, despite the growth in volumes moving to the market. Tunisian demand is also expected to tick up at the end of 2019 with the start up of TSP capacity at M'dhilla.

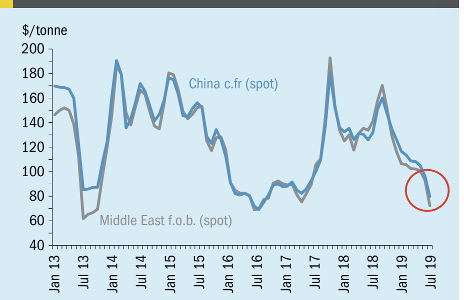
In Central Africa, Kamoto Copper Company (KCC) is currently building a new sul-

Fig. 1: **Monthly average sulphuric acid prices**




*Source: Argus Media*

Fig. 2: **Monthly average sulphur prices**




*Source: Argus Media*







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phur burner and $SO_2$ facility at Katanga in the DRC. The plant is scheduled to come online at the end of the year and would lead to an increase in sulphur trade into the country.

Buyers in India appear to be covered in the short term, following a spate of spot purchases that led to the c.fr price dropping below $100/t c.fr for the first time since mid-2017. Iffco is receiving monthly supply from IOC in the domestic market, potentially limiting spot interest from the buyer. Indian sulphur imports rose by 6% in the first six months to 633,000 tonnes. Middle East sulphur accounted for over 83% of imports, with the UAE at the top of the list at 358,000 tonnes, up by 62% year on year.

## SULPHURIC ACID

Global sulphuric acid prices continued on a downward trend into July before reaching a point of stability in August. The lukewarm processed phosphates market and downward trend in sulphur prices has weighed on the acid market in recent months. Further price decreases are likely before a potential uptick in prices in the new year.

South Korean and Japanese smelter acid suppliers have been largely focused on contract trade, with limited spot volumes available. High stocks in major outlet regions alongside the already weak market has impacted prices in Asia. The South Korean/Japanese export price has dropped from the $70s/t f.o.b. at the start of the year to less than $20/t f.o.b. in August. Production from Japanese smelters was balanced, with some upcoming fourth quarter maintenances expected to limit spot trades. On the export front, there has been a 33% rise in trade from Japan in the month of July year on year. However year to date trade data shows a 4% drop overall, with substantial maintenance works conducted at Mitsubishi's Noashima smelter during the first quarter. Looking ahead, major smelter acid producer Pan Pacific Copper is set to run a 40 day maintenance at its Saganoseki smelter starting in October.

The ramp up in domestic smelter acid production in China has led to new entrants into the global export market such as Chinalco this year. At the same time, the acid import market in China has been deteriorating, adding to the downward pressure in pricing in Asia. Export prices dropped to $11/t f.o.b. on the low end of the range in August, raising questions around whether export volumes would see a slowdown during this period of low pricing. Acid exports from China fell to a 14 month low in the month of July – with limited global demand. However, January-July 2019 exports show a 149% surge year on year to 1.2 million tonnes. Chile has been the leading market at 490,000 tonnes while Moroccan shipments were up 160% at 321,000 tonnes.

Purchasing activity in southeast Asia has been limited due to depressed appetite, with delivered acid prices dropping in line with export values. Prices fell from $85/t c.fr in March to the $40s/t c.fr in August.

European producers have also focused primarily on contract commitments recently, with the NW European region balanced to tight over the summer months. There are a number of outages in Europe that will limit spot availability in the next few months, and potentially support pricing in any new deals. In Spain, Atlantic Copper's Huelva smelter was believed to be in unplanned shutdown at the start of September. A planned 21 day maintenance at the plant was brought forward as a result. Over in Poland, major smelter producer KGHM started a two month maintenance at its Legnica smelter, from the start of September. Other turnarounds are also planned at smelters in Norway and Sweden.

Chile spot prices fell from $133/t c.fr in March down to $70/t c.fr in June and have remained at this level through to end August. Following an influx of imports on the back of regionally tight supply earlier in the year, ample stocks amid lower consumption rates – prices have been subject to erosion.

Elsewhere in Latin America, Southern Copper was granted a construction permit for its long delayed Tia Maria copper mine project in Peru at the start of July but the company has agreed to delay the start of its construction. The project is set to produce 120,000 t/y copper and consume over 700,000 t/y sulphuric acid.

Acid prices in south east US have been sliding, reflecting the global downturn, reaching lows of $75/t c.fr in June, remaining stable at this level through to the end of August. Supply fundamentals improved in the US slightly at the start of the second quarter on the back of plants returning following maintenance turnarounds.

# Price indications

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

| Cash equivalent | March | April | May | June | July |
|---|---|---|---|---|---|
| **Sulphur, bulk ($/t)** | | | | | |
| Adnoc monthly contract | 108 | 103 | 105 | 102 | 79 |
| China c.fr spot | 135 | 118 | 115 | 118 | 95 |
| **Liquid sulphur ($/t)** | | | | | |
| Tampa f.o.b. contract | 109 | 88 | 88 | 88 | 75 |
| NW Europe c.fr | 130 | 110 | 110 | 110 | 98 |
| **Sulphuric acid ($/t)** | | | | | |
| US Gulf spot | 105 | 105 | 95 | 95 | 95 |

*Source: various*








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1 36
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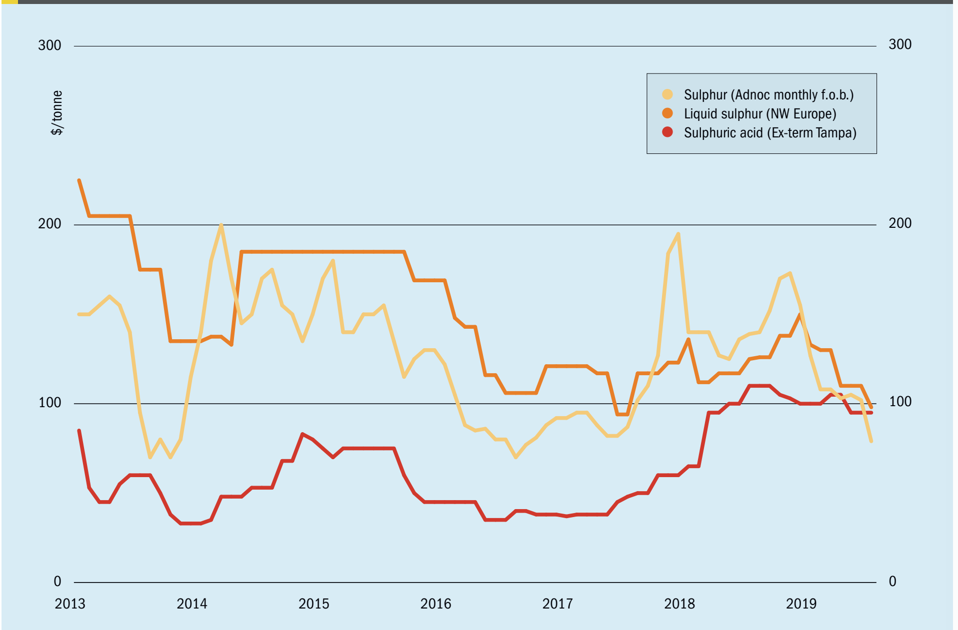
# Market outlook

**Historical price trends** $/tonne




*Source: BCInsight*

## SULPHUR

- Developments in the processed phosphates market will be a major driver for the short term outlook for sulphur trends. No upside is anticipated in the phosphates market until the seasonal shift in Q2 2020. Continued soft DAP pricing could lead to further erosion in sulphur pricing through to the end of the year.
- The market balance in China remains a key factor influencing global pricing and trade. With major DAP producers curtailing production, sulphur consumption is set to drop from the fertilizer sector this year. At the same time, sulphur production capacity is rising in the country, potentially influencing sulphur imports and prolonging the bearish tone in the market.
- Fresh new supply from the Middle East is projected to enter the market from 2020, increasing competition in global trade. Kuwait and Qatar appear to be closest to adding significant additional sulphur capacity.
- **Outlook:** Prices are expected to remain stable to soft in the short term with little respite expected until the new year. Downstream markets continue to pull down achievable pricing and limit any meaningful market shift. Upcoming fourth quarter contract negotiations are likely to yield lower prices across most regions due to the softer pricing in the spot market in recent weeks. Uncertainty surrounds the likely impact to the sulphur market of the IMO 2020 regulations due to come into effect on 1 January. Some refineries are expected to recover increased volumes of sulphur due to upgrades while there has yet to be a clear industry consensus on how shipowners will choose to comply.

## SULPHURIC ACID

- Lower prices may negatively impact Chinese exports in the short term, but China is forecast to remain a major exporter in the medium term as new acid capacity comes online as well as rising availability of domestic sulphur.
- Acid demand in the Philippines will see a drop owing to planned maintenance at the Taganito mine in September for two weeks.
- South Korean sulphuric acid exports in January-July 2019 were flat on a year earlier at 1.7 million tonnes. Chile was the leading market at 441,000 tonnes, surging 87% year on year while trade to India was up 29% to 374,000 tonnes. On the back of the shift in Chinese demand and trade, shipments to China dropped by 40% to 287,000 tonnes.
- The closure of Sterlite's Tuticorin copper smelter in India is expected to continue into 2020, removing significant volumes of copper and sulphuric acid from the market.
- **Outlook:** Pockets of regional tightness may provide a floor to price erosion, or further stability into the fourth quarter. Outages at smelters will remove significant volumes from the market but this comes at a time of extreme softness in related markets, likely to limit the upside for acid.







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# Sulphur Industry News

## INDONESIA

### Indonesia to not enforce IMO rules

Indonesia announced last week that it would not enforce the upcoming IMO 2020 rule requiring marine vessels to burn bunker fuels containing no more than 0.5% sulphur on its domestic shipping fleet, making it the first country to indicate that it would not comply with the new regulations. The Indonesian government is concerned about the cost of cleaner fuels in the wake of the changeover on January 1st 2020, and has said that for domestic shipping between Indonesian ports, Indonesian flagged vessels will be allowed to continue burning higher sulphur fuels until the domestic supply of low sulphur fuels was sufficient. It would not opt out of the regulations, but would instead choose not to penalise its own ship operators for using fuel that does not meet the new standard – penalties for non-compliance are to be established by individual IMO member states.

Several other factors have reportedly influenced the government's decision; there is the age of the fleet - Indonesian vessels are often older than international merchant ships, with many between 15 and 30 years old, making replacement parts for engines hard to source. The fleet is also relatively self-contained, with most Indonesian flagged vessels, including 560 tankers moving oil around the country, not leaving the country's waters. The government is also mindful of recent issues that Indonesian ship owners have had with meeting a rule mandating diesel blends contain 20% biodiesel to promote local biofuel use.

Indonesia consumes 600,000 bbl/d of gasoil and fuel oil, mainly in its shipping industry.

## CHINA

### China's to boost LSFO capacity to 18 million t/a

Platts reports that China's top four state-owned refiners plan to boost their combined low sulphur fuel oil (LSFO) production capacity to 18.15 million t/a in 2020. The higher production capacity would allow Chinese refiners to supply LSFO into China's bonded bunker fuel market, and could potentially flip China from a net bunker fuel oil importer to a net exporter, if Beijing announces a highly anticipated tax rebate scheme for overseas sales.

Sinochem reportedly plans to have 550,000 t/a LSFO production capacity at its 12 million t/a Quanzhou Petrochemical by 2020 to meet low sulphur bunker demand for the tighter IMO 2020 emission standards, rising to 1 million t/a of LSFO capacity in 2021 and eventually 2 million t/a.

CNOOC is aiming to more than double its LSFO production from 1.7 million t/a this year to 3.6 million t/a of production in 2020. These are in addition to Sinopec's and PetroChina's previously announced 10 million t/a and 4 million t/a of LSFO capacity, respectively.

China's bunker fuel demand currently stands at around 12 million t/a, and around 90% of this is met through imports into China's bonded zones, which are exempt from taxes, and can be only be used to supply ships on international routes. The planned increases would however turn China from a net importer to an exporter of LSFO assuming all capacity comes on-stream.

## IRAQ

### Sour gas contract to be awarded this year

The state-owned Basra Oil Company (BOC) is expected to award the contract for the sour gas treatment facility at its Majnoon oil field later this year. KBR has completed front end engineering design work on the plant, and three international contractors are reported to have submitted bids for the engineering, procurement and construction contract, estimated to be worth $250 million, including China Petroleum Engineering & Construction Corporation (CPECC), UK-based Petrofac and South Korea's Hyundai Engineering & Construction (HDEC). The EPC contract is part of phase 2 of Iraq's Majnoon oil field development project, and includes construction of a 160 million cfd gas treatment facility, including gas handling, sweetening, dehydration, storage tanks and associated facilities. Output from the Majnoon field is expected to rise from 240,000 bbl/d to 450,000 bbl/d when completed in 2021.

## INDIA

### SRU on-stream from December

Chennai Petroleum Corporation, part of the state-owned Indian Oil Group, says that the revamping of the company's existing diesel hydrotreating unit will achieve mechanical completion by December 2019. The hydrotreater capacity is being raised from 1.8 million t/a to 2.4 million t/a, and a new sulphur recovery unit is being built. The move comes ahead of new Indian fuel quality legislation – so-called Bharat Stage VI, equivalent to Euro-VI – which will come into force from April 1st 2020. Chennai Petroleum is also installing a new 600,000 t/a fluid catalytic cracking gasoline desulphurisation unit with associated facilities as part of the upgrade, which is costed at $2.6 billion, according to the company.

### Subsidies raised for sulphur fertilizers

On August 1st, the Indian Cabinet Committee on Economic Affairs (CCEA), headed by prime minister Narendra Modi, gave its assent to raising the subsidy levels for sulphur-based fertilizers. The move is aimed at discouraging rampant use of nitrogen-phosphorous-potassium fertilizers, which impacts soil quality. For sulphur-based fertilizers, the government will provide a subsidy of 350 rupees/100kg ($4.90/ 100kg), against the previous figure of 277 rupees ($3.87). Subsidies for nitrogen, phosphorus and potassium were unchanged.

"The government's total subsidy burden for nutrient-based fertilizers is 22,875.50 crore rupees ($3.2 billion)," said information and broadcasting minister Prakash Javadekar at a press briefing. "The move is part of steps taken by the Modi-led government to improve agricultural productivity and ease agrarian distress during its second consecutive term."

## SINGAPORE

### Linde expects increased hydrogen for Asian LSFO production

Linde says that Asia's hydrogen gas demand will rise as the region's oil refineries use the gas to produce low-sulphur fuel to meet new IMO and other environmental regulations. Speaking at the ground breaking ceremony for Linde's $1.4-billion gas project on Singapore's Jurong Island, chief executive Steve Angel noted that the demand for hydrogen has grown steadily over the years at a much faster rate than GDP growth, and "the twin drivers of hydrogen have been sour crude feedstock processing (at refineries) and environmental regulations."

The new project is Linde's largest global investment and will quadruple its gas capacity in Singapore. The facility will turn Exxon Mobil Corp's heavy residue fuel into hydrogen and other gases when it starts operations in 2023. Exxon will then use the hydrogen to reduce the sulphur content of fuel produced at its refinery.

Linde believes that in the wake of the IMO 2020 regulations there will be many bottom of the barrel residue gasification projects in Asia to produce hydrogen which can then be used to desulphurise sulphur-containing process streams, allowing refiners to handle cheaper higher sulphur crude inputs.

## EGYPT

### SRU start-up at Zohr field

Eni says that it has now started up all of the sulphur recovery units as part of the Zohr gas field development. In a statement the company said that a second 30" pipeline has now been completed, along with two wells in the south of the field (in addition to the 10 already drilled in the north) and all have gone into operation, and that gas production from the Zohr field has now reached 2.7 bcf/d, paving the way for an increase to its plateau rate of 3.2 bcf/d by the end of the year, five months ahead of schedule.

Zohr, an offshore field in the Mediterranean Sea, is the largest gas discovery in Egypt. Eni holds a 50% stake of the production block, Rosneft 30%, BP 10% and Mubadala Petroleum 10%. KT Kinetics Technology developed the SRU process scheme at Zohr based on its *RAR*™ multipurpose process for acid gas enrichment and tail gas treatment; a KT modified Claus process and liquid sulphur degassing technology. There are four 12 t/d SRUs in Phase 1 and a further three 12 t/d units in Phase 2 of the development.

## UNITED ARAB EMIRATES

### Adnoc launches second tender for Manayif gas plant

Adnoc has launched the second onshore contract for the $4 billion Manayif sour gas plant, part of the joint development of the Ghasha and Hail offshore sour gas fields, located in shallow water off Abu Dhabi's north-west coast. The packages cover gas compression platforms, drill centres and subsea pipelines, as well as the offshore gas-processing plant. In February, the National Marine Dredging Company was awarded the $1.4 billion EPC contract for the 10 new artificial islands that are at the core of the estimated $10 billion project. Production of 1 billion cfd of gas is due on stream in 2024-25.

Russia's Lukoil has said in July that it will be taking a 5% stake in the Ghasha development, with final negotiations now underway. The project is currently 60% held by the Abu Dhabi National Oil Company (ADNOC), with the remainder held by Italy's Eni (25%), Germany's Wintershall (10%) and Austria's OMV (5%).

### Eni buys 20% stake in ADNOC Refining

Eni says that it has closed its deal with the Abu Dhabi National Oil Company (ADNOC) to acquire a 20% equity stake in ADNOC Refining at a cost of $3.24 billion. ADNOC Refining processes 922,000 bbl/d of crude at its Ruwais and Abu Dhabi refineries. The transaction is one of the world's largest-ever in the refining business and reflects the scale, quality and growth potential of ADNOC Refining's assets, Eni said in a statement. Ruwais is the 4th biggest single-site refinery in the world.







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# Sulphuric Acid News

UNITED KINGDOM

## Trafigura takes control of Nyrstar

Commodity trader Trafigura Group has become the majority owner of Nyrstar, owner of Europe's largest zinc smelter. The deal follows a debt restructuring agreement arranged with Nyrstar's creditors to avoid Nyrstar's bankruptcy. Creditors will receive a package of Trafigura debt securities in exchange for them writing off debt. Agreement was also reached with the State of South Australia on the restructure of securities relating to the Port Pirie lead smelter. Nyrstar has been working to restructure its debts since October after an unexpected profit warning sparked a selloff in the company's shares and bonds. Nyrstar operates six smelters and several mines in Europe, North America and Australia, with a total output of 1.3 million t/a of sulphuric acid.

"The closure of this capital restructuring is excellent news for both Trafigura and Nyrstar," said Jeremy Weir, executive chairman and chief executive officer of Trafigura. "The macroeconomic environment is positive for zinc concentrate and refined zinc metal markets on a forward looking basis, and Nyrstar will be very complementary to our existing trading activities. As an independently operated company within the Group and with its restructured and strengthened balance sheet, there is now the opportunity for Nyrstar to realise its full potential".

Daniel Vanin has been appointed CEO of the operating business of Nyrstar with immediate effect.

"Nyrstar begins a new chapter today," said Daniel Vanin. "I've already visited almost every Nyrstar operation around the world. I've been impressed by the fundamental strength of the assets, by the depth of technical knowledge of the teams and by their passion for the work that they do. I've seen many opportunities and solutions that could be implemented quickly. We will also be able to draw on Trafigura's technical, economic and other commercial expertise," concluded Daniel.

Over the next few months, a new headquarters will be established at Nyrstar's operations at Budel, in the Netherlands. Members of Zurich-based staff whose roles are affected have already been informed of these plans, with the employee consultation process having taken place during July. ■

UNITED STATES

## Gunnison receives first acid shipment

Excelsior Mining says that it has received the first delivery of sulphuric acid at its Gunnison copper project in Arizona, and remains on schedule for first copper production in the final quarter of 2019. The company completed construction of three acid storage tanks in July with capacity of 7,500 tonnes and a new acid unloading facility.

"The pure sulphuric acid in these tanks is diluted down to a weak sulphuric acid mining solution via the new acid handling and delivery system. This weaker acid solution is used in the wellfield operations to leach the copper from the naturally fractured rocks below ground," said COO Roland Goodgame in a statement.

Gunnison, the first new copper project to be fully permitted in the US in over a decade, is an in-situ recovery copper extraction project permitted to produce 57,000 t/a of copper cathode. Triple Flag Mining Finance provided a $75 million funding package to build the mine, comprising a $65 million copper stream and a $10 million private placement.

DEMOCRATIC REPUBLIC OF CONGO

## Glencore to idle Mutanda mine

Glencore says that it plans to halt production at its Mutanada cobalt and copper mine in the DRC at the end of 2019, following a "significant decrease" in prices for cobalt. Cobalt prices rose sharply during 2017 due to expectations of increased demand for batteries for smartphones and electric cars. Prices peaked in March last year at $94,500/tonne. However, during late 2018 and 2019 they have fallen sharply, down by around 40% this year to below $26,000/t, due to a world glut in supply, itself mainly due to output increases from the DRC, the world's largest producer of the metal. Around 10,000 tonnes of cobalt reportedly remains unsold at Mutanda. The mine will now operate until the end of 2019, at which time Glencore says that the facility will be placed on "care and maintenance".

Glencore also blamed increased input costs for key raw materials, particularly sulphuric acid. In a letter to workers at the mine, it said: "due to the significant decline in the price of cobalt, increased inflation in some of our main inputs (mainly sulphuric acid) and additional taxes imposed by the mining code, the mine is no longer economically viable in the long term."

Last year's new mining code increased government royalties on 'strategic' minerals from 2% to 10%. However, a bigger disruption has been Zambia imposing import taxes on copper concentrate exports from the DRC, which has caused production interruptions at Zambian smelters and hence interrupted exports of smelter acid from Zambia to the DRC.

EGYPT

## New phosphate complex inaugurated

Egyptian president Abdel Fattah al-Sisi has officially inaugurated construction work at the Al Nasr For Intermediate Chemicals Company's $274 million phosphate and compound fertilizers complex on the Red Sea coast at Ain Sokhna, 30km south of Suez. Once complete and operational – which is not due until 2026 according to the Egyptian government – it is claimed that the complex will be the largest of its kind in the Middle East and Africa, comprising nine separate plants for fertilizer production. It forms part of the country's plans to monetise domestic natural gas and phosphate resources.

The project consists of two sulphuric acid plants with a capacity of 570,000 t/a; two phosphoric acid plants with a capacity of 180,000 t/a; a monoammonium phosphate plant with a capacity of 90,000 t/a, a diammonium phosphate plant with a capacity of 360,000 t/a, and a triple superphosphate plant with a capacity of 2.25 million t/a. thyssenkrupp Industrial Solutions has also been contracted to build an ammonia plant at the site to feed MAP/DAP production.

AUSTRALIA

## King River rescales proposed Speewah acid plant

Exploration and mining company King River Resources Ltd, which is developing the Speewah Specialty Metals (SSM) project, says that it has decided to rescale aspects of the project as part of the pre-feasibility study. The aim is to reduce





CONTENTS



SULPHUR
ISSUE 384
SEPTEMBER-OCTOBER 2019

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the start-up capital requirement to build the project without impacting significantly upon operational margins. The company says that it believes that the estimated costs of building a beneficiation, agitation leaching and metal recovery plant can be reduced to around A$525 million by reducing its start-up mining rates to operationally correspond with a more standard-sized sulphuric acid plant installation. The planned sulphuric acid plant has therefore been scaled back to a 1,800 t/d plant which will also produce 15MW of electricity. King River is also trying to identify optimum process routes to produce vanadium pentoxide, titanium dioxide, iron oxide products and other high value products like high purity alumina and magnesium oxide from the project. It expects to complete the pre-feasibility study towards the end of 2019.

### NQ Minerals looking at integrating acid output

NQ Minerals plc has made a further strategic investment in Tasmanian mining company Tasmania Energy Metals Pty Ltd. The company had previously committed $550,000 to Tasmania Energy Metals via three recent convertible loans, and has now signed a new loan, allowing NQ to extend its exclusivity period during which it has the right to acquire all of Tasmania Energy Metals' assets. These include nickel-cobalt exploration and mining licenses and 100% control of the integrated minerals processing facility currently being developed to treat material from NQ's Hellyer mine. The two companies are continuing to work on plans for an integrated facility, using sulphuric acid from the treatment of the pyrite/precious metals concentrate produced from the Hellyer mine in the production of nickel and cobalt salts for sale into the electric vehicle battery market.

## CHINA

### Shenghong opts for acid alkylation

DuPont Clean Technologies has been awarded contracts to supply Shenghong Petrochemical Group Co., Ltd with a *STRATCO*® alkylation technology license, engineering, and proprietary equipment. Shenghong is undertaking a project to design and construct a new alkylation unit as part of its grassroots petrochemical and refining facility with crude oil capacity of 16 million t/a (320,000 bbl/d) located in Lianyungang City, Jiangsu Province, China. The alkylation unit at the Shenghong facility will be designed to produce 440,000 t/a (11,000 bbl/d) of alkylate product, allowing the refinery to generate low-sulphur, high-octane, low-Rvp alkylate with zero olefins that meets the upcoming China VI fuel standards which will take effect prior to the start-up of the Shenghong facility in 2021.

"DuPont looks forward to working with Shenghong on this exciting, new opportunity, as the company sets out to build a world-leading petrochemical industry park," says Kevin Bockwinkel, Global Licensing Business Manager, *STRATCO* alkylation technology. "We were very pleased an alkylation unit had been included in the complex configuration as Shenghong is looking for the most efficient way to make high quality fuels in its cutting-edge crude-to-chemicals plant."

*STRATCO* is a leading alkylation technology with over 100 units licensed worldwide and more than 33 million t/a (850,000 bbl/d) of installed capacity. It is a sulfuric acid catalysed process that converts low-value olefins into high-value alkylate, a key desirable component for clean fuel.

### Tighter regulations on copper concentrate

The Chinese government has launched a consultation on imposing stricter controls on copper concentrate imports, reducing the permitted level of arsenic and other heavy metals. Currently levels of 0.5% arsenic are permitted; the new draft standard would reduce this to 0.4%. While the move is aimed at reducing pollution from copper smelting, there are worries that the move could severely disrupt copper concentrate imports into China, the largest importer of concentrate for metal smelting, and could lead to a demand for blending plants outside China to blend purer grade concentrate with concentrate that does not meet the new regulations.

Zijin's new smelter at Qiqihar City, Heilongjiang.

PHOTO: ZIJIN MINING

### Zijin Mining starts up new copper smelter

Zijin Mining began trial production at its new copper smelter at Qiqihar City in China's northern Heilongjiang province on August 18th, according to the company. Commissioning was expected to continue through September. Once the smelter reaches capacity, some time next year, it will be producing 150,000 t/a of copper cathode, as well as 600,000 t/a of sulphuric acid.

## INDONESIA

### Freeport secures financing for smelter

Freeport's Indonesian subsidiary, the country's largest gold and copper miner, says that it has secured a $3 billion financing commitment from eight foreign and three domestic banks, putting it a step closer to completing a critical smelter by December 2023. The company must complete the huge copper smelter to fulfil its part of the deal with the government, allowing it to continue operations at its Grasberg mine in Papua until 2041. The Indonesian government has cracked down on exports of copper and nickel concentrate to China, aiming instead to secure more value from its mineral deposits by processing the metals domestically.







Freeport Indonesia is currently building the 550,000 t/a smelter in the Java Integrated Industrial and Ports Estate in Gresik, East Java. It has invested $150 million of its own funds in feasibility studies, engineering services, environmental impact analyses, rental fees and soil maturation for site preparation. The company switched its contract of work agreement to a special mining business permit last year after intense negotiations, which saw the Indonesian government becoming the company's majority owner.

Freeport Indonesia currently produces about 3 million t/a of copper concentrate in Indonesia, 1 million t/a of which is now processed domestically in Indonesia by Smelting, a joint venture with Japan's Mitsubishi in Gresik. Smelting also processes 100,000 tonnes of concentrate from Medco Energy Indonesia, producing a total of 290,000 t/a of copper cathode, as well as 1.05 million t/a of sulphuric acid, which goes to state-owned Petrokimia Gresik for fertilizer production.

### Nickel ore export ban brought forward

Indonesia has announced that it will enforce a complete ban on the export of raw nickel ore from January 1st 2020, two years earlier than planned. The aim is to speed up the construction of domestic nickel smelters, part of Indonesia's aim to capture more value from its mineral exports. Indonesia has 36 nickel smelters under construction, taking its domestic nickel ore demand from 24 million t/a to 81 million t/a. The smelters will be able to process low grade nickel ores for batteries to help Indonesia increase its production of electric vehicles. Exports of nickel ore totalled 13.3 million tonnes in the first seven months of the year out of 23.6 million tons of ore cleared for shipment. Shipments were 20 million t/a in 2018, with the government issuing recommendations for a total of 76.3 million tons since the ban on exports was relaxed in 2017.

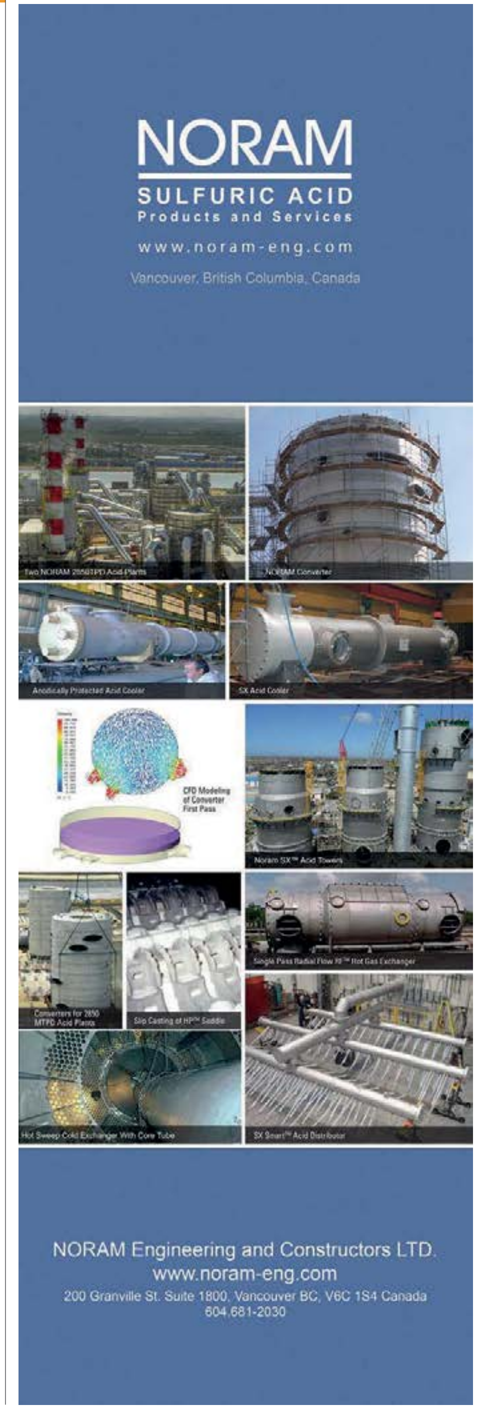
## CANADA

### Glencore cancels smelter upgrade

Glencore Canada says it has cancelled the final stages of a C$64 million upgrade at its smelter in Belledune, New Brunswick. The move follows months of dispute with 280 union workers at the site over contracts. The lead/silver smelter employs 450 people. Members of the United Steelworkers union began a strike in April over the company's refusal to pay salaries for a union president and safety official, and the smelter was forced to run at 54% capacity with lower staffing levels. Glencore was in the process of spending C$64 million on upgrading the acid plant at the decades old smelter. The first, C$20 million phase was already complete, but work was due to begin on the second phase in July. The smelter's sulphuric acid capacity before the revamp was 180,000 t/a. ■

The Port of Belledune, with the smelter in the background.

PHOTO: PORT OF BELLEDUNE










SULPHUR
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# People

**Daniel Vanin** has been appointed Chief Executive Officer of the operating business of Nyrstar with immediate effect, following the takeover by Trafigura. According to Nyrstar, with 40 years in the industry, he brings extensive international mine and smelting development experience, alongside strong management skills to the role. "Nyrstar begins a new chapter today," said Daniel Vanin. "I've already visited almost every Nyrstar operation around the world. I've been impressed by the fundamental strength of the assets, by the depth of technical knowledge of the teams and by their passion for the work that they do. I've seen many opportunities and solutions that could be implemented quickly. We will also be able to draw on Trafigura's technical, economic and other commercial expertise," concluded Daniel.

Vanin has worked in the mining industry for over 40 years in both underground and open pit mines, and with smelting operations in both Chile and Bolivia. During this time he has gained international mine and smelting development and management skills, coupled with extensive experience of working around the world, including in Canada, Russia, Spain, and in several African and South American countries. He joined Trafigura in 2011, as Chief Operating Officer of the company's Mining Group, having previously been the Chief Executive Officer of Iberian Minerals Corp. Prior to this, he held senior executive and operational positions with Cambior Inc., RBG Resources PLC, Glencore, Lac Minerals Ltd, and High River Gold Mines.Daniel works in English, French, Italian and Spanish. He is an Italian national who grew up and studied in Canada, graduating from McGill University with a degree in Mining Engineering.

**Michel Prud'homme**, the senior director of the International Fertilizer Industry Association's (IFA's) Production and International Trade Committee, retired on June 28th. Prud'homme held the position for 19 years, helping to produce all of IFA's trade forecasts and outlooks and representing the organisation at numerous international conferences and events. Prior to joining IFA, Prud'homme, a Canadian geology graduate from Montreal, worked for 19 years as an economist with Natural Resources Canada.

At IFA's international conference in mid-June in Montreal, the organisation elected **Mostafa Terrab**, chief executive of Morocco's OCP group, as chairman of the association. Terrab becomes the first chairman from the African continent of IFA in its 90-year history. He succeeds Rakesh Kapur, joint managing director of IFFCO, India. Terrab holds a Ph.D in Operations Research from MIT, and previously worked as the first Director General of the Moroccan National Telecommunications Regulatory Agency (ANRT) and at the World Bank before joining OCP in 2006.

"I am honoured to take on this important responsibility" said Mr. Terrab. According to IFA, sustainable nutrient use, science-based approaches to plant nutrition and capacity building are among Mr. Terrab's top priorities for his chairmanship. Soil fertility across much of Africa is low. Over 40% of African soils face nutrient depletion, partly because of a failure to apply sufficient levels of fertilizers. As a result, average crop yields are only a fraction of those enjoyed by other regions and risk not keeping up with the continent's growing need for food. To meet demand, sub-Saharan Africa must triple the amount of cereals it produced in 2007 by 2050. This is in the face of many challenges in the coming decades, such as water scarcity and climate change.

"By scaling up improved soil analysis and nutrient best management practices, farmers in Africa can increase the efficiency and productivity of their farms and avoid the additional conversion of an estimated 80 million hectares of additional land to desert," Mr Terrab said.

Mr Terrab also pledged to increase efforts to attract more youth and women into roles across agriculture. Mr Terrab's chairmanship follows an extensive strategic assessment of the industry, investigating how it can further contribute to the world's broader sustainable development goals.

Nutrien CEO and president **Chuck Magro** was also elected vice chairman of IFA.

## Calendar 2019/20

**SEPTEMBER**

16-20
Brimstone Sulphur Symposium,
VAIL, Colorado, USA
Contact: Mike Anderson, Brimstone STS
Tel: +1 909 597 3249
Email: mike.anderson@brimstone-sts.com

**OCTOBER**

7
Brimstone Sulphur Recovery Fundamentals Course, HOUSTON, Texas, USA
Contact: Mike Anderson, Brimstone STS
Tel: +1 909 597 3249
Email: mike.anderson@brimstone-sts.com

7-10
Middle East Sulphur Plant Operators Network (MESPON), ABU DHABI, UAE
Contact: UniverSUL Consulting,
PO Box 109760, Abu Dhabi, UAE.
Tel: +971 2 645 0141
Fax: +971 2 645 0142
Email: info@universulphur.com

**NOVEMBER**

4-7
European Refining Technology Conference (ERTC), WARSAW, Poland
Contact: Sandil Sanmugam,
Conference Manager, World Refining Association
Tel: +44 20 7384 7744
Email: sandil.sanmugam@wraconferences.com

4-7
CRU Sulphur and Sulphuric Acid 2019 Conference, HOUSTON, Texas, USA
Contact: CRU Events
Chancery House,
53-64 Chancery Lane,
London WC2A 1QS, UK.
Tel: +44 20 7903 2167
Email: conferences@crugroup.com

**FEBRUARY 2020**

Date T.B.A.
Laurance Reid Annual Gas Conditioning Conference, NORMAN, Oklahoma, USA
Contact: Tamara Powell, Program Director
Tel: +1 405-325-2891
Email: tsutteer@ou.edu

**MARCH**

8-10
Phosphates 2020 Conference,
PARIS, France
Contact: CRU Events
Tel: +44 20 7903 2167
Email: conferences@crugroup.com

22-24
AFPM Annual Meeting, AUSTIN, Texas, USA
Contact: American Fuel and Petrochemical Manufacturers (AFPM)
1667 K Street, NW, Suite 700,
Washington, DC 20006, USA.
Tel: +1 202 457 0480
Email: meetings@afpm.org
Web: www.afpm.org





CONTENTS
What's in issue 384
COVER FEATURE 1
Sulphur + Sulphuric Acid conference, Houston, Texas
COVER FEATURE 2
Sour gas projects
COVER FEATURE 3
Sustainability in sulphur recovery
COVER FEATURE 4
Sulphur enhanced fertilizers

SULPHUR
ISSUE 384
SEPTEMBER-OCTOBER 2019

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Phosphate rock mining in Florida.

PHOTO: MOSAIC

# North American phosphates

In spite of several high profile closures, US phosphate production remains a major consumer of sulphur, but demand continues to shrink as the industry rationalises.

The phosphate industry has a long history in North America, beginning in the 1830s in North Carolina. The US was the largest producer of phosphate rock in the world throughout the 20th century, and its industry had a global reach. However, there has been a relative decline over the past couple of decades as competition has evolved elsewhere. US production of phosphate rock peaked in 1980 at 54.4 million metric tons, and this had more than halved to 25.7 million t/a in 2018, as mines have become exhausted. Consequently the US has been overtaken as the world's largest phosphate miner, first by China, which is now by far the world's largest phosphate rock producer, and more recently (in 2014) by Morocco. Canadian phosphate rock mining was never as large as that in the US, and in 2013 Agrium closed Canada's last operational phosphate rock mine in Kapuskasing, Ontario, after the reserves there were exhausted, and began instead importing phosphate rock from Morocco to supply its phosphate fertilizer plant at Redwater, Alberta. In the US, phosphate rock mining is concentrated in central Florida and Idaho, although there are also mines in North Carolina and Utah (see Figure 1).

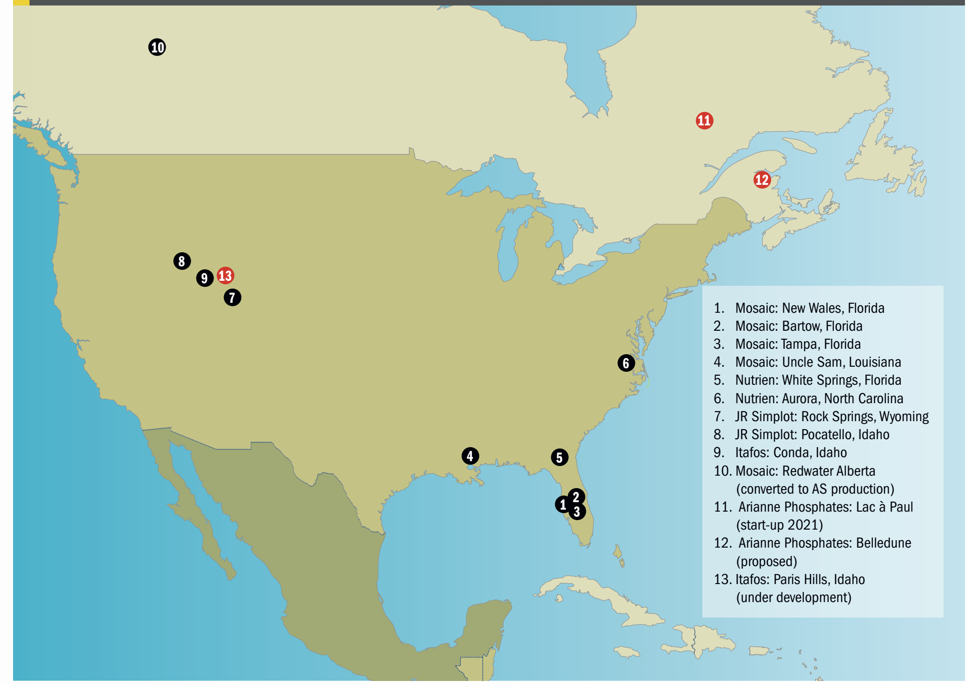
As mined rock tonnages have fallen, North American demand for phosphate rock has begun to run slightly higher than the region's mined output. In 2017, the region imported 3.5 million tonnes of phosphate rock to feed phosphoric acid production. Almost all (about 90%) of US demand for phosphate rock is for fertilizer production. The rest goes mainly to animal feed, some phosphoric acid is used in the food industry, there is some direct rock application to soil, and some is used in the production of elemental phosphorus. As a developed economy, US fertilizer demand for phosphate is relatively mature, and for most of the 1990s and 2000s fluctuated between 3.8 million t/a $P_2O_5$ to 4.3 million t/a $P_2O_5$. Canada adds another 400-500,000 t/a $P_2O_5$ to this figure. However, there has been a pickup in demand in the past few years, due to increased plantings of maize and soybeans, which are more phosphate-hungry, as opposed to declining plantings of wheat, which uses less phosphate fertilizer.







Fig. 1: **North American phosphate plants**




## Downstream

North American production of phosphoric acid in 2017 was 13.9 million t/a in terms of tonnes product (7.5 million tonnes $P_2O_5$). Only 3% of this figure was represented by Canadian production, at Redwood, Alberta, with the remainder coming from the US. US downstream phosphate production is mainly aimed at mono- and diammonium phosphate, accounting for 2.9 million t/a $P_2O_5$ and 1.6 million t/a P205 respectively.

As with phosphate rock, so the North American share of downstream phosphate production has steadily fallen since the mid-1990s. In 1995 North America claimed 45% of global phosphoric acid production, but the rise of China in particular and closures in North America has brought that share down to 15% in 2018 – still significant but not the dominant force it once was.

## Companies

As phosphate rock mining and processing has shrunk in North America, the shape of the North American industry has changed by a process of consolidation. In the 1990s there were 18 different companies operating phosphate plants in the United States at 22 different sites. However, a continuous process of consolidation has seen that reduced to just four; Mosaic, Nutrien, Simplot and Itafos, with only nine major phosphate processing sites now in operation.

### Mosaic

Mosaic is the largest phosphate producer in North America, with 60% of regional capacity. It was originally formed by the merger of Cargill's crop nutrition division and IMC Global in 2004, and boosted by the acquisition of CF Industries in 2013, and Vale Fertilizantes in Brazil in 2018.

Mosaic operates four phosphate mines in Florida, at South Fort Meade, South Pasture, Wingate and Four Corners, which between them produced 14 million t/a of phosphate rock in 2018. In addition, there are three downstream phosphate facilities in Florida, at Mulberry/New Wales – the largest phosphate operation in the US – as well as at Riverview and Bartow. Phosphoric acid production in Florida for Mosaic was 3.25 million t/a in 2018 (tonnes $P_2O_5$).

There is also the old Freeport-Agrico plant at Uncle Sam, Louisiana, which was bought by IMC Global in the 1990s. Finished phosphates are produced here using phosphate rock from Mosaic's Peruvian subsidiary.

One of Mosaic's largest decisions in recent years has been to close its Plant City facility in Hillsborough County, Florida in 2017. Plant City produced 1.3 million t/a of finished phosphates in 2017, but was one of Mosaic's higher cost facilities.







SULPHUR
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## Nutrien

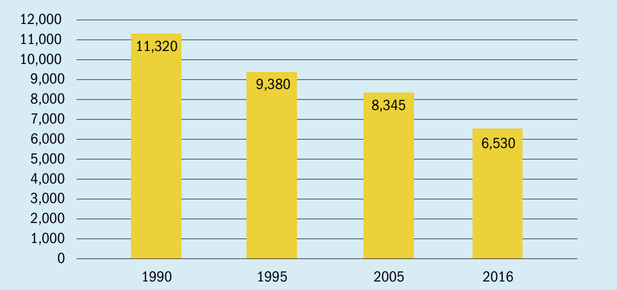
Based in Saskatoon, in the Canadian province of Saskatchewan, Nutrien was the result of the 2017 merger of PotashCorp (formerly the Potash Corporation of Saskatchewan or PCS) and Agrium, also Canadian, but based in Calgary, Alberta. While, as the name suggests, PCS/PotashCorp was always focused on its potash mining assets, it also has significant phosphate and nitrogen assets.

Following the merger, Nutrien took the opportunity to reorganise its phosphate operations and end overseas imports of phosphate rock. The company closed its phosphate facility in Redwater, Alberta, which previously relied on imported phosphate rock from OCP, and has reconfigured the plant to produce ammonium sulphate instead using ammonia from the Redwater site. It also closed its smaller Geismar, Louisiana phosphate facility at the end of 2018, which also relied on imported phosphate rock. Instead, Nutrien is increasing production of mono-ammonium phosphate (MAP) and other products at its phosphate facilities in Aurora, North Carolina and White Springs, Florida. Both of these facilities are supplied by their own rock mines. Nutrien also has four smaller regional upgrading plants at Harrison, Ohio, Joplin, Missouri, Marseilles, Illinois, and Weeping Water, Nebraska, which produce feed and industrial products. Nutrien had a capacity of 1.7 million t/a (tonnes $P_2O_5$) of finished phosphates in 2018; 24% of North American capacity.

## JR Simplot

JR Simplot, headquartered in Boise, Idaho, is a diversified agribusiness company with a production and distribution network concentrated across the western United States and Mississippi-Missouri river valley. One of the few producers to have remained relatively unchanged over the past two decades of consolidation, it was founded by Jack R Simplot to supply potatoes to the Macdonalds hamburger chain, but moved into mining in the 1960s. It operates two phosphate mines at Smoky Canyon, Wyoming, and Vernal, Utah, which in turn feed downstream processing sites at Pocatello, Idaho and Rock Springs, Wyoming respectively – the latter is fed by a slurry pipeline from Vernal. Simplot has 11% of North American phosphate capacity, about 800,000 tonnes $P_2O_5$.

Fig. 2: **US sulphur consumption for phosphate production, '000 t/a**




*Source: Acuity*

## Itafos

Founded in Toronto in 2008 as the MBAC Fertilizer Company, the company changed its name to Itafos in 2017. It began by developing phosphate capacity in Brazil, via its Itafos Arraias subsidiary, but bought into the North American market in 2017 via the acquisition of Agrium's Conda, Idaho site just before Agrium merged with PotashCorp to become Nutrien. Itafos is the smallest of the North American producers, with its single site at Conda. It has 5% of North American phosphate capacity, around 550,000 t/a of MAP and merchant grade phosphoric acid. It is however looking at developing a 1 million t/a phosphate mine at Paris Hills, Idaho.

## Exports

The North American phosphate industry was traditionally a large exporter of finished phosphates. Back in the 1990s, China was the largest importer of ammonium phosphates. However, at the same time at North American production has run down, so Chinese production of phosphate rock and ammonium phosphates has expanded dramatically, turning China into the largest exporter of DAP. Falling production and increased competition on the global market has meant that North American exports of phosphates have consequently contracted dramatically – from 12 million t/a of DAP/MAP and TSP in 1996 to less than 3 million t/a in 2018, and North America's share of the international phosphate trade fell from close to 60% to just 10% during that time.

## Global connections

Another of the notable developments of the past decade or so is that the North American phosphate producers have gradually developed more of a global presence. Mosaic has been the most notable here; as well as its North American operations, Mosaic has a majority (75%) owned joint venture called Miski Mayo which operates a phosphate mine at Bayovar in Peru. Bayovar mined 3.9 million t/a of phosphate rock last year, which feeds Mosaic's Louisiana phosphate operations. Mosaic also bought into Brazil in 2018 via its acquisition of Vale Fertilizantes, and the company now has a significant presence in Brazil, one of the fastest growing markets for phosphates in the world. Mosaic Fertilizantes has five phosphate mines in Brazil (two of them idled earlier this year due to permitting issues over tailings dams), and five downstream processing plants, mainly in Minas Gerrais state. Finally, Mosaic has a 25% stake in a joint venture with Ma'aden in Saudi Arabia; the Wa'ad al Shamal Phosphate Company, which mines phosphates in the northwest of Saudi Arabia near the border with Jordan, and transports them by rail to the Red Sea coast at Ras al Khair for downstream processing. Mosaic is increasingly globally focused, and this has caused some to question the future of some of its US operations, especially in Louisiana, which relies on rock imports from several thousand miles away.

Itafos of course has its Brazilian subsidiary, with 500,000 t/a of single superphosphate (SSP) production at Tocantins, but it is developing a 1.3 million t/a phosphate rock mine in Guinea Bissau, due to come into operation in Q1 2021, according to the company. It is also looking into a feasibility study on a phosphate rock mine in Peru as well an integrated phosphate complex in Brazil.

The others have so far lagged behind. Nutrien has a presence in Brazil and Australia, and nitrogen capacity in Trinidad and Argentina, but for the moment remains North American focused. Likewise JR Simplot has agribusiness connections in Asia, Australia and Latin America but has not ventured much outside North America on the phosphate side.

## New projects

Although phosphate production is running down in the US, there are still new projects on the horizon. The main new prospective phosphate producer in North America is Arianne Phosphates, which is developing a phosphate mine and beneficiation complex at Lac a Paul in Quebec, Canada. The deposit was not discovered until the 1990s, and has only been under active development since 2008.

The Lac à Paul project will comprise an open-pit phosphate mine in the Saguenay-Lac-Saint-Jean region, which will mine 55,000 t/d to produce 3 million t/a of phosphate concentrate. Government approval was secured in 2015, and last year approval was granted for a maritime export terminal on the north shore of the Saguenay River. Mine commissioning is now set for 2021, according to Arianne.

There is also a feasibility study underway on developing a 500,000 t/a phosphoric acid plant at Belledune in New Brunswick, using steam and fresh water from a nearby power plant and sulphuric acid from Glencore's Brunswick lead smelter to process 1.4 million t/a of the phosphate concentrate from the mine. Around 1.5 million t/a of sulphuric acid will be required, probably leading to imports of sulphuric acid to the side in addition to acid from the smelter.

## Further rationalisation?

The US phosphate market continues to be affected by the growth in production of finished phosphates elsewhere in the world, especially Morocco, a lower cost producer. With the continuing run-down of US phosphate mines, there is an assumption that there may be further industry rationalisation and consolidation ahead.

## Sulphur demand

The quantity of sulphur required to feed North American phosphate production has naturally fallen as phosphoric acid and finished phosphate production has fallen. Acuity Commodities estimate that in 1990, 11.3 million t/a of sulphur was required to feed phosphate production in North America, but by 2005 that had fallen to 8.3 million t/a, and by 2016 just 6.5 million t/a (Figure 2). The closure of Plant City will have had another knock on that total figure. Even so, this is still a significant source of sulphur demand.

The North American sulphur industry has itself reconfigured to deal with the changing situation, caused in part by falling sour gas production in the US and especially Canada, and rising production from refineries, especially on the US Gulf Coast. The cost of deliveries of molten sulphur by rail from Canada has prompted Mosaic to invest in a 1 million t/a sulphur melter at its New Wales site, allowing it to import formed sulphur from potentially cheaper overseas sources to operate its phosphate operations. This in turn has driven more sulphur forming capacity in western Canada, to allow for some of the molten sulphur to be exported from the port of Vancouver instead.







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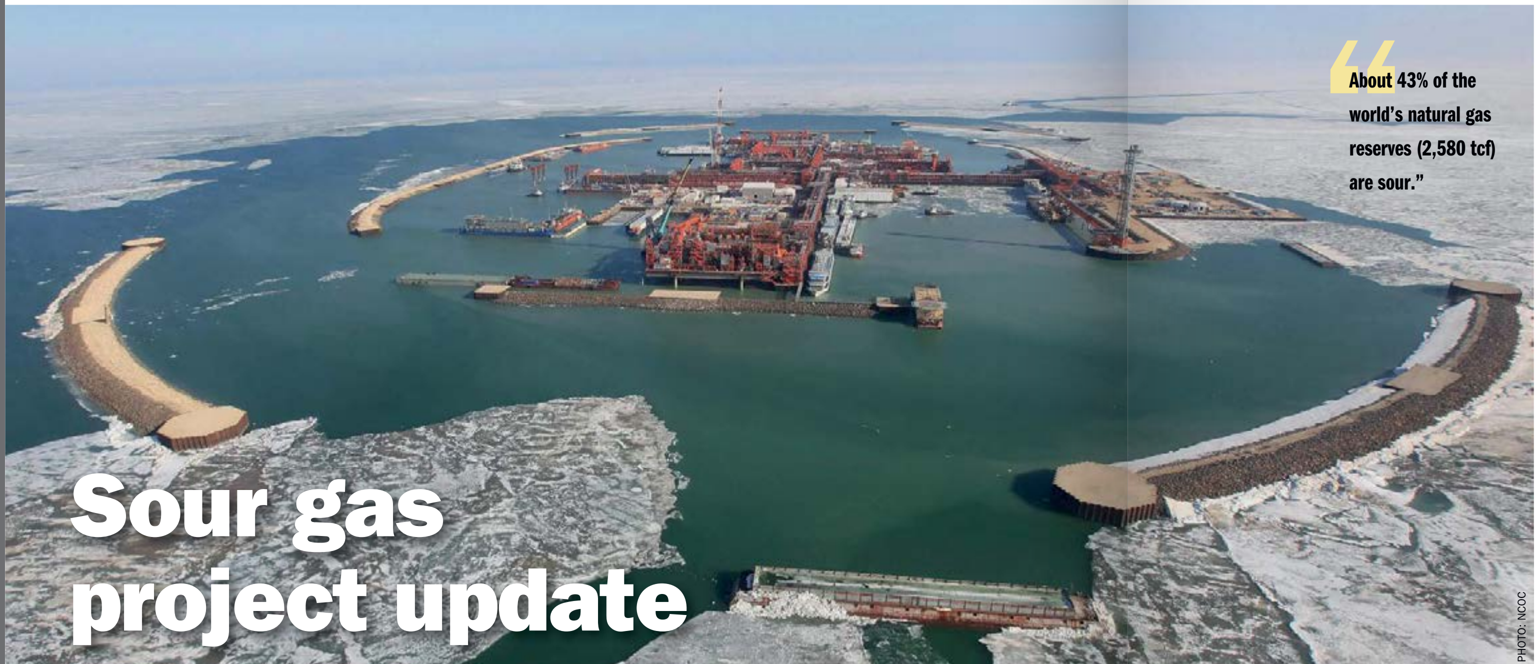


“About 43% of the world’s natural gas reserves (2,580 tcf) are sour.”

# Sour gas project update

Sulphur production from sour natural gas will continue to be the largest slice of new sulphur capacity over the next few years.

*The Kashagan sour oil and gas project, Kazakhstan.*

The modern sulphur industry has grown up on sour gas production, initially in western Europe and Canada, but quickly spreading to other regions. Definitions of what is ‘sour’ vary; most natural gas has some hydrogen sulphide content. At the lower end, definitions of sour as having values of more than 4 ppm, 24 ppm or 100 ppm hydrogen sulphide relate to equipment and pipeline tolerances for corrosion, as well as safety in the event of accidental release, and the International Energy Agency similarly defines it as natural gas with concentrations of $CO_2$ and $H_2S$ “that exceed the concentrations specified for commercially saleable natural gas”. However, from a sulphur industry perspective, these levels of $H_2S$ are relatively trivial in terms of tonnes of sulphur recovered, and a broader definition of sour or very sour gas tends to include all feed gas with an $H_2S$ concentration of more than 0.7-1.0%.

According to the International Energy Agency, outside North America, about 43% of the world’s natural gas reserves (2,580 tcf) are sour. In the Middle East, which has the world’s largest sour gas reserves, the figure is 60%, while for Russia, the world’s largest natural gas producer, 34% of total reserves are classified as sour. Because of the difficulty, danger and additional expense in extracting and processing sour gas, sour gas processing has tended to be the last option for countries that have sweet fields they can tap. However, while in North America sour gas production continues to run down as fields mature and cheaper, sweeter shale gas undercuts the cost of sour gas extraction, in other regions of the world a need for gas supplies locally has driven some nations to start tapping sour gas fields. And elsewhere, sour gas associated with oil production has forced some nations to process sour gas in order to extract oil. Three regions in particular are now driving new sour gas projects; the Middle East, Central Asia, and China, and all of these are having a knock-on impact on sulphur production and sulphur markets globally.

## Middle East

Much of the Arabian Gulf has offshore highly sour or moderately sour gas reserves, in areas claimed by Saudi Arabia, Iran, Qatar and Abu Dhabi, but the gas fields extend under most of the western United Arab Emirates (UAE) and across into Oman in the east. Ample supply of gas from sweeter sources meant that most of these fields were left untapped for many years, but pressure of demand from rapidly expanding economies in Saudi Arabia and the UAE is now starting to lead to widespread exploitation of these sour gas resources. Foremost among the developers of these projects has been the Emirate of Abu Dhabi.

## Abu Dhabi

Abu Dhabi has rapidly risen to become the region’s largest sulphur producer and exporter over the past few years to become the largest sulphur producer in the world, with around 7 million t/a of sulphur capacity – more than 10% of global production – in 2018, as comparted to just 2 million t/a in 2013. The pressure for development has come from the rapid growth of the city of Abu Dhabi and its need for electricity. The Emirate runs a gas deficit of 18 bcm per year. As a result it has turned to its large sour gas reserves. Two huge processing plants – Habshan and Shah – now take highly gas from across the Emirate and strip it of its significant $H_2S$ content – an average of 23% at the Shah field. Sales gas production at Habshan is now 1.5 billion scf/d and sulphur production around 10,000 t/d (3.3 million t/a). Shah processes 1.0 billion scf/d of sales gas, but as the gas is sourer at Shah its sulphur production is actually 3.5 million t/a.

Abu Dhabi continues to focus on new sour gas projects. There are plans to expand production at Shah – a 60-40 partnership between the Abu Dhabi National Oil Co (Adnoc) and Occidental Petroleum – to 1.5 billion scf/d of sales gas by 2022-23, which could see an additional 1.7 million t/a of sulphur production. Adnoc has also recently announced contract awards for new offshore sour gas projects, as part of the so-called Ghasha Concession, which covers a series of gas fields west of Abu Dhabi city, including the Hail, Ghasha, Dalma, Nasr and Mubarraz offshore sour gas fields. Adnoc is being partnered in the development by Eni, which has a 25% stake, and Wintershall, with 10%. The ultimate aim is to produce collectively 1 billion scf/d of sales gas in the second half of the next decade in order to provide sufficient for electricity generation for another two million new homes, at an estimated cost of $20 billion.

## Iran

Iran has been developing the South Pars field via a 28-phase development plan which has been ongoing for two decades, including gas production and associated onshore facilities, gas and condensate processing and downstream petrochemical works. Sanctions on Iran, especially US financial sanctions, have complicated the development of the field, and last year French major Total said that it was exiting the long-delayed $4.8 billion Phase 11 of the project, although by November Iran had persuaded the China National Petroleum Corporation (CNPC), which already had a 30% stake in the project, to also take Total’s 50% share. Completion of Phase 11 may now not be until 2022-23. However, with the exception of this, the Pars Oil and Gas Company says that all other phases of the South Pars development plan will be complete by March 2020. Iran produced 1.6 million t/a of sulphur in 2018, and South Pars expansions could see this rise by another 300,000 t/a over the coming years.

## Qatar

Qatar mainly processes slightly sour (ca 1% $H_2S$) gas from the huge offshore North Field to feed the massive LNG and GTL complex at Ras Laffan, on the northern tip of the Qatar peninsula. Currently, sulphur recovered from these facilities is sent to the Common Sulphur Facility at Ras Laffan, where it is formed and exported. Total sulphur recovery at Ras Laffan is running at just over 2 million t/a.

Qatar rapidly expanded its LNG export capability in the 1990s and 2000s, but put a moratorium on new gas developments from 2011-2017. The main exception was the Barzan LNG project, which was under development prior to the moratorium. Development here has run slowly, however, exacerbated in 2016 by leaks in the gas pipeline running from the production wells to the mainland, requiring new lines to be laid – a similar problem to the Kashagan project in Kazakhstan.

*The Shah processing plant, Abu Dhabi.*






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Barzan is now – according to state operator Rasgas – due to start up towards the end of 2019, with its 6 LNG trains being fed by 1.7 bcf/d of gas and condenstate in the first phase, rising to 2.5 bcf/d by phase three. An additional 800,000 t/a of sulphur will be recovered at capacity from the gas destined for Barzan, taking output at Ras Laffan to 3 million t/a.

Qatar is now looking to raise LNG exports from 77 t/a to 110 million t/a by 2024 with four new LNG trains, each of 8 million t/a. Chiyoda is performing FEED work on the associated North Field Development Project to provide gas for the LNG facilities. Another 1 million t/a of sulphur will be produced from the new facilities once at capacity.

## Saudi Arabia

Saudi Arabia's gas demand is rising rapidly for electricity production, as the country tries to phase out its old oil-burning power stations to free up more oil for export. However, the country's gas production is mainly from associated gas and therefore production can be constrained by OPEC quotas. To overcome this Saudi Arabia has turned to its standalone gas reserves, most of which are sour, and therefore, like Abu Dhabi, Saudi Arabia has found itself increasingly having to process highly sour gas fields. The Kursaniyah gas plant started up in 2012, followed by the Wasit sour gas plant in 2016, with a gas processing capacity of 2.5 billion scf/d and sulphur production of 1,200 t/d. Gas for these facilities comes from the offshore Karan, Arabiyah and Hasbah sour fields.

The next new gas plant will be Fadhili, which will take 2.5 billion scf/d of sour gas from an expansion of the Arabiyah-Hasbah fields. Construction began in 2016, and Saudi Aramco says that it is due to become operational at the end of 2019. Sulphur production at capacity is expected to be 4,000 t/d (1.3 million t/a).

## Oman

Oman is mostly focused on boosting its oil production, but there are some sour gas projects as well. Most of the work is being undertaken by Petroleum Development Oman (PDO), a company majority owned (60%) by the Government of Oman, with additional participation from Shell (34%), Total (4%) and Partex (2%). The first sour gas play, the $4 billion Rabab Harweel Integrated Project, is a joint venture between PDO and Petrofac and came onstream in July this year. Gas at the Rabab reservoir is 2-3% $H_2S$, but in the first phase the sour gas is being reinjected into the Harweel oil reservoir for enhanced oil recovery. The other project, however, Yibal Khuff Sudair, aims to tap the Khuff deep oil and associated sour gas deposit beneath an existing field, with an $H_2S$ content for the gas of 3%, and will produce sales gas. An 85,000 t/a sulphur recovery plant is complete, and commissioning of the gas project is expected in 2021.

## Central Asia

The area of sour gas exploitation in Central Asia is mostly around the Caspian Sea region, in Russia to its west, Kazakhstan to its north and east, and the zone of sour oil and gas reserves extends further south east into Turkmenistan and Uzbekistan. Onshore deposits in Russia and Kazakhstan are the longest standing and most mature, with discoveries going back to the 1960s and exploitation to the 1980s, while new exploration has focused on offshore reserves in the North Caspian and onshore reserves into Turkmenistan.

## Russia

Russia already has two major sour gas processing plants. The first is at Astrakhan on the west side of the Caspian Sea, which processes highly sour (up to 25%) gas from the Krasnoyarsky gas/condensate field, operated by Gazprom. Sulphur output was more than 4.0 million t/a in 2018, and represents most of Gazprom's output, mainly destined for export. The second is at Orenburg, a Soviet era gas processing plant which also processes production from across the Kazakhstan border at Karachaganak, which is run by KPO, a consortium consisting of ChevronTexaco, Agip, BG, Lukoil and KazMunaiGaz. Total sales gas production at Orenburg is 1.5 bcf/d, and $H_2S$ content averages 2-6%. Sulphur production was 1.1 million t/d in 2018, and is mainly for domestic use within Russia.

New oil and gas projects on Russia's Caspian Sea coast are mainly looking to sweet gas with no sulphur recovery, for example at Rakushechnoye. Lukoil has a sour gas play at Hazri, with three wells drilled so far, where gas is 12% $H_2S$. Hazri is still in an appraisal phase, but Lukoil has said that if it did develop the field it would look to reinject the sour gas.

## Kazakhstan

Kazakhstan has two major sour gas projects, both of which process associated gas from oil production. The longest running is Tengiz, on the northeast side of the Caspian Sea, which is operated by the TengizChevroil (TCO) joint venture, 50% owned by Chevron, ExxonMobil 25%, KazMunaiGaz 20%, and Russia's Lukoil 5%. The $H_2S$ content of the gas is around 16%. Some sour gas is reinjected to boost oil production, but sulphur output was 2.5 million t/a in 2018. TCO had produced large stockpiles of sulphur but these have been mostly drawn down now.

The second major project is Kashagan. When this huge oilfield was found in 2000, it was the largest discovery in 50 years, although its exploitation has been fraught with problems due to difficulties with geology; a very deep (4.2km) high pressure reservoir and very sour (17%) $H_2S$ associated gas. Difficult conditions such as winter ice and the high partial pressure of $H_2S$ have posed problems for the North Caspian Operating Company (NCOC) which is developing the project, a consortium of ExxonMobil, Shell, Total, KazMunaiGaz, Inpex, CNPC (which bought out Chevron's stake), and led by Italy's Eni. The expensive and long-delayed project finally came on-stream in late 2013, but sour gas leaks and pipe corrosion forced the replacement of the pipeline system carrying sour gas from the artificial island where the wells are to the onshore processing plant. Oil production reached 340,000 bbl/d earlier this year, and is expected to reach 370,000 bbl/d by the end of the year. Target capacity in Phase 1 is 450,000 bbl/d, with 1.1 million t/a of sulphur production at capacity.

Both projects have expansions planned. The Tengiz Future Growth Project aims to increase oil production by 260,000 bbl/d; virtually doubling current production, with first oil being drilled in 2022. However, sour gas will be reinjected to maintain wellhead pressure, and no additional sulphur is expected. Likewise NCOC said recently that Kashagan production could rise to 500,000 bbl/d in Phase 1, but this would again be achieved via sour gas reinjection.

## Turkmenistan

Turkmenistan has, at Galkynysh (formerly known as South Yolotan), what is estimated to be the world's second largest gas field,





CONTENTS



SULPHUR
ISSUE 384
SEPTEMBER-OCTOBER 2019

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1 36 2 37 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35



with up to 27 tcm of gas in place, at an $H_2S$ content of around 6%, though not all of that is recoverable. This and some subsidiary fields are served by the Galkynysh gas processing plant, which came on-stream in September 2013. Target production in Phase 1 is 30 bcm of gas per year, at which time it is expected to be recovering 1.8 million t/a of sulphur. The latest reports put production currently at around 26 bcm per year.

A framework agreement is in place on further development of the Galkynysh field between Türkmengaz State Concern and a consortium of Japanese firms Itochu, JGC, Mitsubishi, Chiyoda and Sojitz, and Turkish companies Çalik and Rönesans. However, a major pipeline link to India which had been hoped to carry gas from Turkmenistan to markets in the south remains no nearer completion.

## Uzbekistan

Finally, there is a sour gas development at Kandym in Uzbekistan. This is a project being developed by Russia's Lukoil, in partnership with Uzbekneftegaz. It processes 8 bcm per year of sour gas and condensate from six gas fields; Kandym, Kuvachi-Alat, Akkum, Parsanal, Khoji and West Khoji, and was commissioned in 2018. At capacity sulphur production will be 200,000 t/a.

## Caspian Sea convention

Exploration of the Caspian Sea's resources, especially in the southern half, had until recently been complicated by a number of unresolved territorial claims. The previous agreement on the Caspian Sea had been signed by the Soviet Union and Iran, and had considered the freshwater body to be a lake, allowing the surface and – crucially – subsurface to be divided up by the surrounding states. However, some of the new states created in the wake of the breakup of the USSR like Azerbaijan and Turkmenistan wanted to consider it as a Sea, allowing for the application of the UN Law of the Sea, with limits on territorial waters. The agreement signed in November 2018 settles on a halfway house between the two, as favoured by Russia, but establishes territorial waters, a fisheries zone and common maritime space on the surface, as per a sea, but allows the seabed claims to follow existing sectors. Some boundaries are still subject to bilateral negotiation, but the agreement opens the way to further development as it permits the construction of artificial islands, pipelines and removes other ambiguities which had hindered project development.

## North America

Sour gas production in North America continues to run down, with shale gas still commanding the dominant share of the market. Almost all of Canada's natural gas production comes from the Western Canadian Sedimentary Basin (WCSB), which extends from Saskatchewan across northern Alberta and British Columbia and up into the Northwest Territories. Sour gas exploitation began in a serious way in the 1920s and the maturity of the fields makes for diminishing returns. Sour gas production in Alberta, which produces 85% of Canada's sour gas, peaked in 2001, and sulphur production from sour gas in Alberta fell from 6 million t/a in 2001 to 1.7 million t/a in 2016. Since then, however, there has been a modest recovery, to 1.9 million t/a in 2018, due to production increases at existing sites.

Figures from the Alberta Energy Regulator (AER) show that during 2017, the largest sulphur producing sites were: Shell, at Caroline, Waterton and Jumping Pound (364,000 tonnes, 301,000 tonnes and 145,000 tonnes respectively), Husky at Strachan (128,000 tonnes), AEC at Saddle Hills (130,000 tonnes), Samcams at Kaybob South (115,000 tonnes) and Kayera at Strachan (96,000 tonnes) – these seven installations between them accounted for 1.3 million tonnes of sulphur or around three quarters of Alberta's sour gas production.

In the US, production of sulphur from sour gas was 626,000 tonnes in 2018, about half the figure from a decade ago (1.21 million t/a in 2008). Again, maturing gas fields and the shale gas boom have undercut US sour gas production and destroyed much of the economic rationale for developing new fields.

Table 1: **New sulphur capacity in the Middle East, 2018-2023, million t/a**

| Country | Refining | Sour gas | Total |
|---|---|---|---|
| Abu Dhabi | 0 | 1.7 | 1.7 |
| Iran | 0.1 | 0.55 | 0.65 |
| Kuwait | 1.65 | 0.4 | 2.05 |
| Qatar | 0 | 0.75 | 0.75 |
| Saudi Arabia | 0.5 | 1.7 | 2.2 |

*Source: BCInsight*

## China

China's demand for gas is growing faster than any other country in the world, as its government tries to pivot away from its reliance on coal in a bid to reduce pollution and smog as well as lower the country's carbon emissions. This is leaving the country with a growing deficit however. In 2018, China's domestic gas production reached 161 bcm compared to demand of 280 bcm. Over the past five years, annual gas output has increased by an average 9 bcm (7%) just as demand has grown by an average 23 bcm each year , leading to increased imports of LNG and pipeline gas. The International Energy Agency further predicts that between 2018 and 2024, China's demand for gas will increase by 165 bcm per year.

To balance this China is looking to all potential sources of gas to achieve an increase in gas production. Shale gas production has seen a particular boost with Sinopec and CNPC the trailblazers, and there is alos coalbed methane and other unconventional production. Sour gas also forms part of the mix.

China's sour gas fields are mostly in the southern province of Sichuan. Most of the fields were discovered in the late 1990s, and exploration and discovery continued throughout the 2000s

The first to be exploited was Puguang, where there are 410 bcm of reserves with an $H_2S$ content of around 15-17%. The Puguang sour gas processing plant, operated solely by Sinopec, became operational in 2011, and has a maximum gas processing capacity of 1.2 bcf/d, at which point sulphur output would be 3.3 million t/a. Sinopec's other field, Yuanba, began operating in 2014. Sulphur content of the gas is lower here and total sulphur output is expected to be 300,000 t/a. Finally, CNPC is in partnership with Chevron at Chuandongbei. Total proved reserves at Chuandongbei are put at 6.3 tcf, with $H_2S$ content between 7-11%, and target final production of sulphur at 1.2 million t/a.

Chinese sour gas production and hence sulphur output from sour gas has not achieved its targets, however, with the complex geology of Sichuan proving more trying than had been initially anticipated. While output is now starting to rise, last year sulphur from Chinese sour gas totalled only around 2.2 million t/a, much lower than originally anticipated.

## Elsewhere

There is some sour gas production in Europe, especially France and Germany, the former of which, based around the Lacq field, was one of the first sour gas fields to be exploited, in the 1950s. However, again the fields are mature and production and sulphur recovery is declining. There is also some sulphur produced from associated sour gas in, eg Mexico, but the volumes are smaller.

## New sulphur

The fortunes of the major sour gas processing regions of the world vary widely in terms of their prospects for new sour gas production and sulphur recovery. In Europe and North America, production is forecast to continue to slowly decline over the coming years. In China, production is increasing, but the initial impetus towards sour gas production provoked by China's need for new gas supplies (and indeed the country's sulphur deficit, which sulphur from sour gas is helping to erode) has been blunted by some of the difficulties in its actual extraction, and the increases are likely to be ramping up of production at existing sites, adding a few hundred thousand tonnes per year of new sulphur over the next few years.

In Central Asia, one of the major issues is the relative inaccessibility of the gas fields, and the consequent difficulty in exporting sulphur from the region. The solution for TCO in Kazakhstan was to stockpile it, but health and safety concerns, real or imagined, centred on the several million tonne sulphur blocks led the government to force TCO to sell its sulphur stockpile, assisted by a local increase in demand for sulphuric acid for uranium processing. With few major markets nearby, exporting sulphur from Central Asia can be a long a long and tortuous process, often taking weeks along thousands of miles of rivers or rail links, adding additional cost to the process and making the sulphur less competitive with sulphur from less remote locations.

As a consequence, most new oil and sour gas projects in the region, including expansions at existing sites are now looking at sour or acid gas reinjection into the oil wells to boost oil production, including Kashagan and Tengiz. At Kandym in Uzbekistan, the likelihood is that the sulphur will be stockpiled rather than sold, taking it out of the market. At the moment, aside from the continuing ramp-up of production at Kashagan, the main prospect for new sulphur from sour gas in the region comes from any expansion of Galkynysh in Turkmenistan.

All of which leaves the Arabian Gulf, where projects have access to ports for onward export, and where new sour gas production will boost sulphur output. Barzan in Qatar is due to come on-stream later this year or early next, there are continuing project completions at South Pars in Iran, and the Fadhili gas plant in Saudi Arabia will add an extra 1.3 million t/a at capacity. Looking to the slightly longer term, the Shah expansion in Abu Dhabi will bring new sulphur from 2023, and Qatar's LNG projects from 2024. The Hail and Ghasha gas project in Abu Dhabi is likewise currently scheduled for 2023. ■







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# Steel belts for sulphur forming

Tom Smith of IPCO Germany GmbH discusses the history of steel belts in product cooling and forming and new grades of steel that the company has developed to deal with corrosion issues.

The steel belt journey began in 1901 when a conveyor made from a hardened solid strip steel was used for transporting scrap material from a Swedish saw mill. Originally, this strip steel was used for band saws in the lumber industry. Then, thanks to an upgrade in the rolling mills, much longer and wider strips could be produced and the idea came up to use the material as a conveyance medium.

During these early days, applications for steel belts were mainly limited to conveying products from one point to another and the same hardened carbon steel grade used for saws sufficed. However, as industrial development around the world drove the need for steel belts with qualities other than simple strength and wear resistance, the first stainless steel belt was introduced in 1931. This cold rolled stainless material, containing 17-20% chromium and 8-13% nickel, opened the doors to a host of new and exciting applications in the food, chemical and fertilizer industries, where good corrosion resistance, ease of cleaning and protection from contamination were all-important. Eventually, the thermal properties of steel belts were recognized and the first 'process belt' was born.

The pioneering company behind these innovations is today known as IPCO (formerly Sandvik Process Systems), and the company has gone on to become a world leader in the manufacture of carbon, stainless and now duplex steel belts. IPCO steel belts are now used around the world for applications as diverse as baking cookies; pressing wood-based panels such as MDF and OSB; freeze-drying instant coffee; casting thin pharmaceutical films; sintering, and even the wind tunnel testing of racing cars at full speed.

One area in particular – the solidification of chemical melts – has seen steel belt-based cooling come to be accepted as the default process solution for many product types, from A (alkane sulphonate) to Z (zinc stearate), with products in between including bitumen, hot melt adhesives, pesticides, resins, rubber chemicals, and of course sulphur. This in turn has driven continuing improvements in belt technology: the more advanced the application, the greater the need for flatness, straightness and the ability to operate at ever greater speeds and temperature fluctuations.

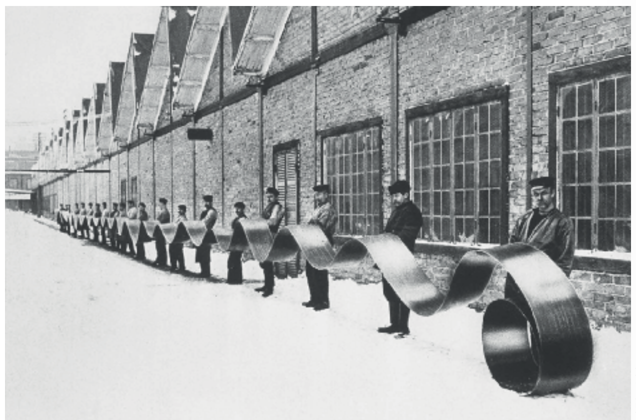

PHOTO: IPCO

*Fig. 1: A hardened, solid strip steel belt from the early 1900s.*

A steel belt might appear to be a relatively simple product but engineering the qualities into the belt necessary to deliver the required performance is a lengthy and exacting process. Today's steel belt manufacturing requires a whole series of production steps in order to remove unwanted characteristics of cold rolled steel such as camber and 'loose' areas providing tighter tolerances for thickness, flatness, surface roughness and straightness. The process includes the following steps:

### Oxide scale removal

The high temperatures required to hot roll the steel into coils results in surface oxidation that manifests itself in the form of a scale that causes a rough surface. This oxide scale must be removed prior to cold rolling. This is accomplished by a combination of mechanical scale breakage and an acid bath treatment known as pickling. With each subsequent process after pickling, the surface area of the steel is increased while the cross section is reduced until the material is cold rolled into a finished strip.

### Cold rolling

Cold rolling requires high pressures since it does not have the softening benefits of the high temperatures used in hot rolling. Therefore, special rolling mills are required to perform cold rolling. For a steel belt, the







SULPHUR
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1 36
2 37
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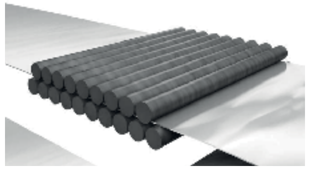

*Fig. 2: Belt levelling.*

*Fig. 3: Longitudinal welding.*

IMAGES: IPCO

*Fig. 4: Edge treatment.*

cold rolled coil must meet certain flatness and straightness specifications. However, the cold rolled coils have varying degrees of long centres and differing compressive and tensile stress patterns throughout the cross-section of the material that need to be levelled in order to meet final tolerances.

## Belt levelling

Belt levelling, also called flattening or trueing, corrects the shape of the cold rolled coil so that the resulting belt is flat and straight. During levelling, the varying internal stresses in the coil are balanced throughout the belt, reducing the risk of belt deformation (the belt losing shape) during operation or heat exposure.

To better explain the concept of levelling, it is necessary to point out what it is that causes a belt not to be straight or flat. If one side of the coil is longer than the other side, the coil will not be straight or run true; this is a condition called camber. To correct the camber, the short side needs to be elongated until it reaches the length of the longer side. To complicate the situation, the longer 'loose' areas and shorter 'tight' areas are not uniform throughout the coil. Belt levelling is considered to be more of an art than a science, and a great deal of knowledge and skill is required to identify these tight areas and how to level them out to match the loose areas in the steel belt.

## Welding

The maximum width of a steel belt depends on the limits of the hot rolling equipment in steel mills. Up until relatively recently, the maximum single width steel belt was 1,500 mm wide. However, in 2005 the first 2,000 mm wide single width material became available; this was a significant development as it enables 33% more forming capacity over the narrower 1,500 mm.

It is possible for multiple belts to be longitudinally welded together to create a wider belt, but for many applications the cost of producing these longitudinally welded belts will be prohibitively expensive. For some markets though (e.g. bake ovens, industrial presses, paper mills), the benefits of a wide belt far outweigh the cost and IPCO regularly produces such belts.

## Edge treatment

Most belts are slit down from a wider coil and the edge cutting and treatment steps in production are crucial to prolong the belt life. Since the belt edge is cut square, it must be machined to a smooth rounded surface to eliminate any sharp corners or burrs.

When a steel belt is in operation, the belt edges can be exposed to high stresses from belt tensioning and tracking or from possible pulley misalignment. Rounded belt edges help to withstand these stresses. If the edge of the belt gets nicked or burred during operation, it should be immediately retreated and reduce the risk of edge cracks developing. Also, to avoid abrasive damage, anything that may come into contact with a steel belt (i.e. support idlers, product scrapers, etc.) should either be rotating, or made of a softer material than the steel belt grade.

Belt systems need to be inspected regularly – ideally daily – to make sure that the belt is not in danger of damage in any way. In addition, a more detailed inspection should be performed on a quarterly or biannual basis, the frequency depending on the criticality of the operation and whether or not the belt operates around the clock.

*Fig. 5: Edge cracks developing.*

If a crack develops and is noticed in time, it can be repaired on site by a qualified technician. Also, thanks to the repairability of the steel belt materials, if an area has extensive damage, a section of steel belt can be removed and replaced with two intermediate welds.

## Sulphur processing

IPCO steel belts are widely used across the oil, gas and chemical industries and one of the most important applications in this particular field is sulphur processing. The company's experience in this area extends back to 1951, when they installed the first continuous sulphur slating line at an oil refinery in Mexico. Such was its success that the company has gone on to design, manufacture and install more than 700 steel belt-based Sulphur forming machines around the world, producing either slates or pastilles.

The forming or solidification process works by delivering molten sulphur onto a continuously running stainless steel conveyor belt. Cold water is sprayed onto the underside of the belt and the excellent thermal conductivity of the steel allows the heat of the Sulphur melt to be transferred to the cooling water as it is conveyed along the system, resulting in a solid formed Sulphur for safe and convenient transportation to end users. The recirculated cooling water is collected in tanks and returned to a water re-cooling system; at no stage does the water contact the sulphur (see Figure 7).

PHOTOS: IPCO

*Fig. 6: Sulphur slates and pastilles*







SULPHUR
ISSUE 384
SEPTEMBER-OCTOBER 2019

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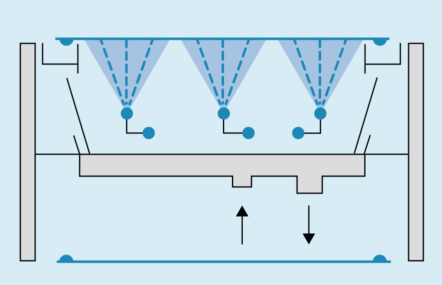
Fig. 7: **Cross-section of a steel belt cooler**



Source: IPCO


PHOTO: IPCO

*Fig. 8: A steel belt cooler producing sulphur pastilles.*

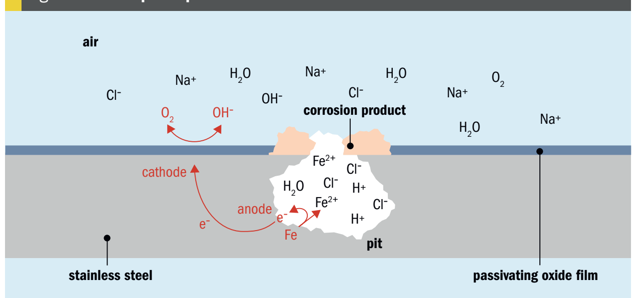
IPCO's designations of steel belt grades will be described in the remainder of this article. For clarity, the IPCO designation of the steel grades gives an indication of both the tensile strength of the steel and the type of steel. The numbers are used to indicate the approximate tensile strength of the steel belt in megapascals (MPa). Letter symbols are used to designate the following steel types:

C = Carbon steel
S = Stainless steel
A = Austenitic steel
M = Martensitic steel
F = Ferritic steel

For example, IPCO grade 1200SA is an austenitic stainless steel with a tensile strength of approximately 1,200 MPa; whereas, 1400SAF is a duplex steel stainless steel made up from a mix of austenitic and ferritic steels with a tensile strength of approximately 1,400 MPa. For universal familiarity, the European standard steel number is shown in parentheses after each steel belt grade designation.

Historically, a standard austenitic steel belt – IPCO grade 1200SA (1.4310) – has been used for sulphur forming. However, plants installed in warm regions and near seawater are exposed to high levels of airborne chlorides and moisture that combined with elemental sulphur can result in pit corrosion of the steel belts and, eventually, lead to the development of edge cracks. Pit corrosion occurs when the passive layer on the stainless-steel surface is locally broken down by halide ions, such as by chloride ions, in a neutral or acidic environment. As a result, pitting and crevice corrosion can propagate at a high rate, causing corrosion failure in a short time. While pits in a steel belt appear to be small holes in the surface, the actual corrosion below the surface can be much greater (Figure 9).

Fig. 9: **An example of pit corrosion below the surface**




Source: IPCO

## IPCO 1400SAF

In order to tackle this challenge, IPCO has recently introduced a steel belt made of duplex stainless steel that offers significantly greater resistance to chlorides and wet sulphur contact corrosion. Most of the sulphur recovered these days is from oil and gas refining and many refineries are located near seaports for ease of exportation. IPCO grade 1400SAF (1.4462) is a steel grade that is highly alloyed of the elements chromium, molybdenum and nitrogen, which provides enhanced reinforcement of the passive layer of the surface. This makes it ideal for use in Sulphur plants that are located close to salt water, especially in countries where ambient temperature can reach 30-40°C.

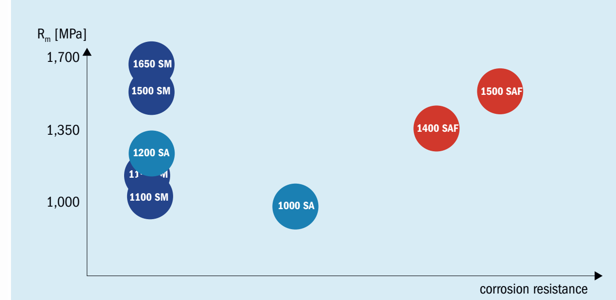
To make a rough ranking of different stainless steels, the PRE (pitting resistance equivalent) formula is used, PRE = % of Cr + 3.3 x % of Mo + 16 x % of N. IPCO grade 1400SAF has a PRE of 35, in comparison IPCO 1200SA has a PRE of 18 and IPCO 1000SA (1.4401) has a PRE of 24. The higher the PRE value, the better the resistance.

Stress corrosion cracking (SCC) is a brittle failure mode caused by the combined effect of mechanical stress in a corrosive environment and normally at elevated temperature. SCC is often initiated by a localized corrosion attack (pitting or crevice attack). Standard austenitic stainless steels containing less amounts of molybdenum are more sensitive to SCC than other types of stainless steels. The 1400SAF grade has a very good resistance to stress corrosion cracking due to its duplex microstructure of austenite and





Fig. 10: **Steel belt grades tensile strength versus corrosion resistance**




Source: IPCO

ferrite where the ferrite phase is the continuous phase. Also, the material has a low carbon content and thereby a high resistance to intergranular corrosion.

Reference installations are proving that the 1400SAF duplex steel is much more resistant to corrosion from high chlorides in the presence of wet sulphur with belts running much longer than the standard 1200SA stainless steels without signs of pit corrosion or cracking. While sulphur installations away from sea water have seen great success for decades with the 1200SA steel grade, IPCO is standardising on its 1400SAF duplex steel for all sulphur installations from now on since other airborne chlorides could be present in any location.

IPCO has continued development and is also now also able to offer a 'super duplex' grade 1500 SAF (1.4410) for installations where chloride levels are particularly high or there is a risk of hydrochloric acids coming into contact with the steel belt. The diagram left shows how IPCO's different steel belt grades rate for tensile strength and corrosion resistance.

The SM grade belts shown in the diagram are all martensitic precipitation-hardened stainless steels. These martensitic grades have a thermal conductivity that is comparable to the austenitic grades, but the thermal expansion is much lower. This makes the precipitation-hardened steel less sensitive to thermal strain and buckling caused by uneven temperatures. However, they are more sensitive to pitting than the austenitic grades, even in solutions of a relative low chloride content, and are not recommended for processing sulphur-based products.

While mechanical forces remain to be the most common cause of damage to steel belts, IPCO continues to develop new steel grades like the 1400SAF duplex steel to resist damage that can be controlled, like corrosion, to prolong the life of steel belts. ■







SULPHUR
ISSUE 384
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**Donald Loftus**, Senior Principal Consultant, Regeneration Services for Veolia North America, explains the increasing drive towards sulphuric acid alkylation and regeneration in refineries.

*The Veolia Red Lion Plant in Delaware, which regenerates spent sulphuric acid and recovers sulphur-containing gas from a nearby refinery.*

# Industry's interest in the circular economy

The circular economy delivers value by diverting waste from disposal to production of quality products that are competitively priced, and which have a smaller environmental footprint than those made with virgin materials. Simply put, the circular economy relies on eliminating waste through reuse and recycling.

Oil and gas companies strive to achieve 100% reliability with no unplanned shutdowns and increased throughput in their downstream plants to maximise profitability. Part of that effort increasingly relies on reusing and recycling their materials. For example, refineries typically convert their acid gas containing $H_2S$ to elemental sulphur using Claus and tail gas units. With the help of Veolia, refineries in New Jersey and Texas have replaced the typical Claus and tail gas units with units that produce sulphuric acid for both sale and beneficial reuse in alkylation units in the refineries.

While refineries provide a great example, the circular economy solution extends to other industries using sulphuric acid in their chemical applications as well. Non-alkylation spent acid or spent acid from non-refinery customers such as pharmaceutical companies or makers of microchips can also be brought in and processed for beneficial reuse.

## Growth in alkylation

At present in the US market, gasoline production and alkylation capacity are running at near all-time highs. Similarly, spent sulphuric acid regeneration (SAR) is running at, or very near, capacity for most suppliers. With higher-octane gasoline required to meet Corporate Average Fuel Economy (CAFE) standards, there will be an increasing demand for alkylate and in turn, for spent SAR for refiners that utilise sulphuric acid alkylation.

Although it is not the only way to increase octane in gasoline, alkylate is the component of choice for gasoline blenders. Alkylate has very favourable environmental characteristics: low sulphur, lower vapour pressure and high motor octane value, among others. Many consider it the environmentally preferred octane additive when stacked up against other alternatives.

Steady macro drivers can also be associated with the growing long-term demand for alkylate, such as the need for higher-compression engines in vehicles and lower vapour pressure requirements.

Additionally, the economics for alkylate manufacturers have improved significantly: margins are high, and producers of alkylate are receiving a good return on their investment. Historically, situational drivers have also helped expand the alkylate market, such as when tetraethyl lead (TEL) was phased out, when methyl tert-butyl ether (MTBE) was deselected as a fuel additive in the US, or when ethanol made its way into the fuel pool, and alkylate was added to keep the vapour pressure within specification.

Over the next two to seven years, we will see another phase of growth that will be associated not only with the demand side, but with the supply side, as well. Fortunately, the raw materials needed to manufacture alkylate are plentiful and available at reasonable costs. This business environment adds up to a large, profitable and growing alkylate market.





ACID ALKYLATION

## Managing spent acid

Essentially, refiners have two options for managing spent sulphuric acid generated from alkylation production: an onsite facility or a merchant facility.

In the merchant facility model, a refiner ships its spent sulphuric acid to an offsite, third-party facility for processing. The spent acid is processed and sent back to the refinery as fresh acid. This process is a good model, particularly for refineries that have moderate to low alkylation capacity, and the benefits are primarily reliability and an economically viable solution for SAR that helps reduce a company's environmental footprint.

In addition to servicing the refinery's needs, a merchant facility may also handle chemical spent acid from an electronics plant or other manufacturers. The plant may also produce high-value sulphur derivative products for other applications, such as detergents or shampoos. Ultimately, a merchant plant has scale advantages when given the right market demand for the products.

With the onsite model, a refiner can either build its own facility, or engage a third party to design, build, own and operate the facility for them. In this case, the third party can provide key sulphur management services for the refinery by processing all of its spent acid, along with all or some of its sulphur-bearing gases. The benefits of the onsite model are multi-faceted, and include onsite regeneration of spent sulphuric acid at a viable cost, with guaranteed availability and again, a reduced environmental footprint. An onsite plant uses the refinery's acid gases as feedstock to produce sulphur-based products, and deliver high-pressure steam back to the refinery for its use in production. The refiner benefits from reduced transportation and load/unload infrastructure costs.

The onsite option is ideal for refiners with significant alkylation capacity, or those that are adding units to expand alkylation capacity. This is particularly true if acid gas requirements are increasing, and/or the existing gas handling infrastructure is challenged or outdated. The economics are ideal, allowing the refiner to eliminate non-value-added logistics, have greater reliability and manage both spent acid and acid gases at the same facility.

While the US is currently leading the world in terms of alkylate production, the international market is beginning to increase alkylate production, as well. In particular, China is considering alkylation production as a way to promote cleaner air. India and several Latin American markets are also looking at potential growth in alkylation production.

If the need continues to rise at its current rate, regenerated sulphur and sulphur gas could become critical parts of the equation.

## Veolia North America

In addition to providing many other environmental services to municipalities and industry, Veolia North America owns and operates seven plants under its Regeneration Services division.

They provide spent acid regeneration, convert sulphur gas to sulphuric acid, and directly produce sulphuric acid and other sulphur-based products from elemental sulphur. In addition, its Acid Technology Centre provides more than 30 engineers, scientists and technicians who support the sulphur plants and their customers. They solve problems, provide consultations, devise solutions and offer critical safety training. ■







CONTENTS



SULPHUR
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SEPTEMBER-OCTOBER 2019

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# CRU Sulphur + Sulphuric Acid conference 2019

CRU welcomes delegates to its annual Sulphur + Sulphuric Acid conference that takes place 4-7 November 2019 at the Hilton Americas, Houston, USA. For more than 30 years, the conference has been a premier event for anybody working in sulphur and sulphuric acid production, consumption and trade to come together to meet, learn, share experiences, discuss challenges and do business.

CRU's Sulphur + Sulphuric Acid conference is the annual global gathering for the sulphur and sulphuric acid industries, providing extensive content and networking opportunities over four days. The conference and exhibition attracts over 480 delegates, representing sulphur and sulphuric acid operators, producers, buyers, sellers and solution providers.

The four-day agenda incorporates key market insights on supply, demand and price, with in-depth technical content focused on practical applications of technology, equipment and operations know-how.

The 2019 agenda includes a panel discussion on IMO 2020, chaired by CRU, with panellists representing refiners, shippers, brokers and regulators who will be sharing their views on the impacts of the IMO Marpol regulations that come into force on 1 January 2020.

The topic of this year's sulphuric acid workshop will be heat recovery from acid plants and will focus on various aspects of engineering, specifications, operation and maintenance of heat recovery systems from the energy rejected from acid systems.

In parallel to the sulphuric acid workshop there will be a sulphur operations and troubleshooting clinic providing participants with the opportunity to ask questions and share problems and experiences relating to their sulphur operations. ■

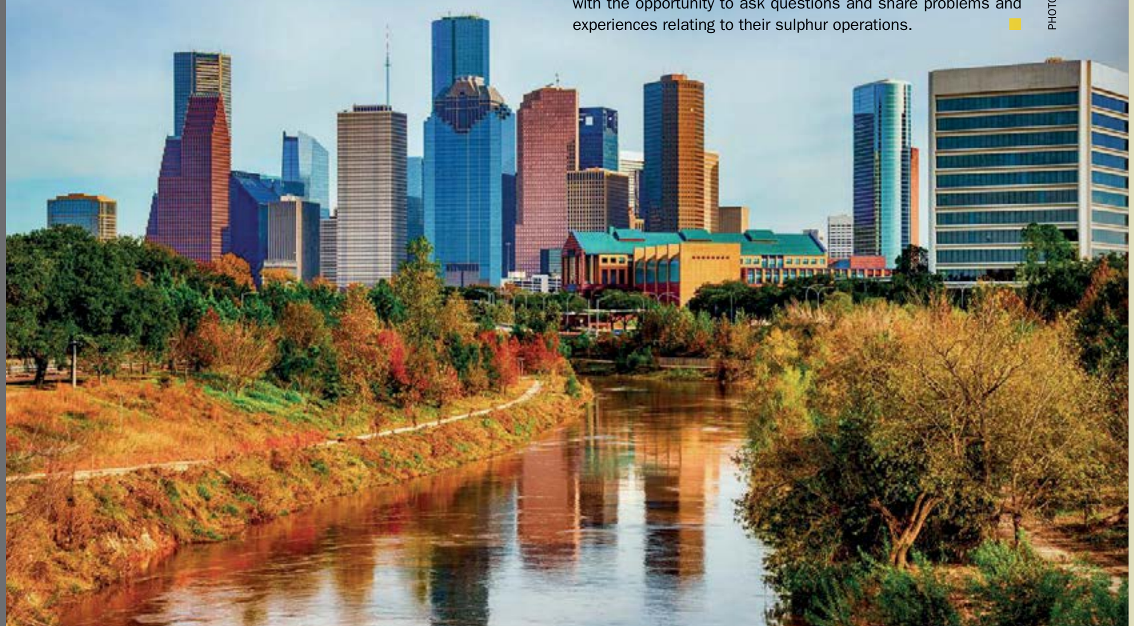

PHOTO: ISTOCKPHOTO.COM/ART WAGER





## PRE-CONFERENCE EVENTS

### SITE VISIT: Galveston Sulphur Terminal

**Monday 4 November, 08:00 – 13:00**

Conference delegates will have the opportunity to sign up for a site visit to Galveston Sulphur Terminal, hosted by Savage Services. The site tour will include a presentation of the Galveston Terminal and a bus tour of the facility.

The Galveston Terminal, owned by Gulf Sulphur Services Ltd., LLLP (GSS) provides sulphur producers and consumers access to a wide range of sulphur handling services. The terminal has the capability to receive and ship liquid sulphur by a number of transportation modes. It has a permitted capacity of 3.5 million tons, with forming and blocking capability. The terminal can receive molten sulphur by tank truck, railcar, inland class barges, and ocean-going tankers. The terminal can ship out sulphur in molten form by truck, inland class barges, and ocean-going tankers. After forming, the formed or prilled sulphur is loaded onto bulk marine vessels for export via a traveling ship loader located on the main dock at the terminal. The terminal started operation in 1969, is situated on 72 acres of land in the Port of Galveston, and is located on the Island of Galveston, Texas.

### WORKSHOP: Operation of SRUs – A practical overview

**Monday 4 November, 09:00 – 12:30**

Comprimo will be hosting a workshop on the operation of sulphur recovery units (SRUs).

Refinery SRUs are receiving increasing attention in recent years since the regulatory emission demands and energy efficiency/$CO_2$ footprint have become more important. In this interactive workshop, Comprimo subject matter experts will guide delegates through the main points of consideration when operation an SRU including the tail gas treating units. Practical aspects to consider when taking a SRU out of operation or restarting the SRU will be discussed. In addition the workshop will focus on the new features that are available to control the SRU. Digital solutions and how it can support SRUs will be shown and discussed as well as options for a simulation model to be able to train SRU operators through console operations.

### WORKSHOP: Sulphur storage tanks

**Monday 4 November, 14:00 – 17.30**

Matrix PDM Engineering will be hosting a workshop on sulphur storage tanks. The unique design considerations associated with sulphur and sulphuric acid storage are driven by operational considerations and the damage mechanisms associated with the products. They differ from standard storage and require expertise in engineering, design and construction coupled with understanding of operational parameters. The storage solutions are a blend of aboveground storage standards such as API 650; corrosion standards such as NACE and operational experiences that affect the functioning of storage tanks. ■

## TECHNICAL PROGRAMME

**Selected highlights**

### Valkyrie – A revolutionary redox technology

**Streamline Innovations Inc.** will showcase a new $H_2S$ removal process that produces high purity elemental sulphur (99.9% pure) with 0 ppmv $H_2S$ emissions. Valkyrie combines the elements of a new patented chelating agent, an exceptional blend of proprietary surfactants, advanced analysis, controls and sophisticated automation, and powerful separation equipment, resulting in the most advanced redox technology every developed. Actual plant data from operating units will be shared, including $H_2S$ removal efficiencies, chemical consumption, sulphur purity, and capex vs opex. Comparisons to other $H_2S$ removal technologies will also be explored.

### Amine solution foaming problems

Foaming is the most common of all amine plant problems, leading to amine losses, off-specification treated gas and low unit throughput, ultimately leading to unit downtime and lost revenues. **Amine Experts** will share field-related experiences in troubleshooting amine foaming episodes in various sour gas processing units. A systemic approached to foaming troubleshooting and long term foaming mitigation strategies will be presented.

### Purification of biosulphur

The THIOPAQ process, a biochemistry based $H_2S$ removal process, is able to process high volumes of $H_2S$ and produces a biosulphur, which has significantly different characteristics to sulphur produced from the conventional Claus process. Due to its composition, it is currently not usable as a raw material for the sulphuric acid industry. **Sulphurnet** will discuss the chemistry and challenges for making this biosulphur suitable as a feedstock for sulphuric acid production.

### Biofuels integration with the refinery sulphur complex

Driven by a global push for environmentally sustainable energy, the integration of renewable diesel facilities within existing refineries has seen an increase in recent years. **Comprimo** will present a case study on the design and potential integration of sulphur complex units into such a facility. It will evaluate the potential for reducing operating costs by integrating the enrichment loop of the acid gas treatment plant as well as utilising the existing infrastructure of the refinery to limit emissions.

### Latest improvements to D'GAASS

Degassing liquid sulphur has a number of benefits including hazard reduction for handling and transportation, improved mechanical integrity of the formed sulphur, and less corrosion of transportation equipment. **Fluor/GAA** continues to improve the performance of its D'GAASS out-of-pit liquid sulphur degassing technology with its new patent pending 3rd generation D'GAASS$^{3G}$ process for new and existing D'GAASS units. Fluor will discuss the latest improvements which include: shorter degassing duration requirements, thus smaller equipment: lower capex and opex, as well as enhanced operating flexibility and reliability through reduced corrosion potential.





SULPHUR
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1 36
2 37
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
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28
29
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32
33
34
35



### TopClaus® – a combination of Claus and WSA technology

**Topsoe** and **Worley** will introduce a new innovative configuration named TopClaus® as the gamechanger for SRUs and discuss its benefits and features. The process recovers sulphur compounds in the tail gas as commercial grade sulphuric acid which can be recycled directly to the Claus reaction furnace for 100% elemental sulphur recovery. The process offers lower opex, capex and $CO_2$ emissions with increased reliability. A case study will be used to highlight the financial and technical payoffs for revamp and grass roots SRUs.

### SRU challenges in refinery projects

**Hindustan Petroleum Corporation Limited** (HPCL) refineries currently handle up to 7 mol-% $NH_3$ in the acid gas feed to the existing SRUs, but this is set to increase. Processing of heavier crudes requires hydrogen-based residue upgrading which results in higher ammonia levels in the SRU feed. HPCL will discuss the various challenges faced during finalisation of the sulphur block configurations in HPCL Mumbai and Visakh Refinery mega projects to achieve sulphur recovery of 99.9%, meeting $SO_2$ emissions requirements and having the flexibility to treat high $NH_3$ (up to 28%) in the acid gas feed to the SRU.

### Contaminated sulphur remelting

As environmental regulations becomes more stringent, it is highly pertinent to address the issue of contaminated waste sulphur stockpiles. **Enersul** will showcase a dirty sulphur remelting system (Enersul ModEx) for a 20% contaminated sulphur remelting application in Alberta, Canada. Challenges, lessons learned and considerations will be shared.

### SRU tubesheet corrosion mechanisms

**Industrial Ceramics** will present the results of a study, based on work carried out in ASRL labs, to investigate the nature of corrosion scale formed by high temperature sulphidation and pre-wet sulphur corroded carbon steel on exposure to a Claus environment.

### The price of start-up, shutdown and turnaround operations

Equipment and instrumentation in amine treating units and sulphur plants behave differently under start-up, shutdown and turndown conditions. Drawing on several case studies, **Optimized Gas Treating** will describe the behaviour of a typical refinery amine unit in start-up, shutdown and turndown scenario conditions and examine the subsequent impact on the SRU. Process configurations will be discussed and assessed.

### Digital solutions and services for acid plants

Digitalisation offers producers opportunities to improve planning, operation and maintenance. **Outotec** will discuss developments in Outotec's digital solutions for gas cleaning and sulphuric acid plants. Potential opportunities for the development of a future autonomous acid plant will also be discussed.

**Topsoe** will describe how two new digital services – a process health monitoring system; and a dynamic operation simulator – can help acid plant operators understand their plants better, and, with this knowledge, improve plant availability and performance. Industrial experience will be presented to show how acid plant operators have (and in other instances could have) benefitted from digital services to overcome the unique challenges of their plants.

### Intelligent sulphur acid production

Utilising historical operational data, big data analysis and a DCS system, Wylton have developed an intelligent sulphuric acid system that is currently in use at its 800,000 t/a sulphur burning acid plant in Dazhou, China. **Wylton** will highlight the operational and maintenance benefits, including the system's ability to perform automatic operation, monitor the health of the plant, and create automatic maintenance plans and solutions.

### Reducing energy consumption and carbon footprint

The New Karvali Fertilizer industrial complex, comprising sulphuric, phosphoric acid, and NPK, is utilising almost 100% of the thermal energy produced from waste heat to power production units. **New Karvali Fertilizer** will share how the plant is decreasing $CO_2$ emissions whilst decreasing energy consumption.

### Designing the world's largest energy recovery system

Utilising the by-product energy from sulphur-burning acid plants can significantly improve plant economics. **Chemetics** will provide an overview of the features and innovations employed in the design of energy recovery systems for two 5,000 t/d sulphur burning acid plants, including design challenges and new materials that are used to address corrosion concerns in specific high-risk areas.

### Zero emissions SAR technology

**P&P Industries** will present a process for Spent Acid Recovery (SAR) from waste gases, including $CS_2$ and $H_2S$ from industrial plants and spent sulphuric acid for incineration. The process allows practically zero $SO_2$ and $SO_3$ emissions and high energy recovery.

### Corrosion protection in sulphuric acid plants

New developments have made it possible to apply organic polymer membranes below brick lining via spray application, which benefits from quick application of seamlessly applied coatings with very good chemical resistance to concentrated sulphuric acid. **STEULER-KCH** will give a brief overview of the capabilities offered by currently available corrosion protection materials and highlight new possibilities afforded by material combinations.

**AGRU America** will provide an update on new applications and long-term references for fluoropolymer products in various high corrosive sulphuric acid applications and will highlight the corrosion resistance properties of fluorinated thermoplastics, in particular, at high concentration and high temperature.

### More out of acid and ore

The recently commissioned Eti Bakir A.Ş. Mazidaği phosphate plant incorporates a sulphuric acid plant in an integrated metallurgical and fertilizer complex. **Outotec** and **Eti Bakir** will describe the flowsheets and interconnections between the various process areas, with a focus on the pyrite roaster, waste heat boiler, gas cleaning and acid plant train. How the plant achieved low emissions and high energy recovery while maintaining acid quality will be shared.

### Shale gas sulphur chemistry

Shale gas produced from certain hot shale gas reservoirs has included the presence of $H_2S$ and organo-sulphur compounds in the production fluid. **ASRL** will detail the research conducted to identify the possible causes of souring.





CONTENTS

What's in issue 384

COVER FEATURE 1

Sulphur + Sulphuric Acid conference, Houston, Texas

COVER FEATURE 2

Sour gas projects

COVER FEATURE 3

Sustainability in sulphur recovery

COVER FEATURE 4

Sulphur enhanced fertilizers

SULPHUR

ISSUE 384

SEPTEMBER-OCTOBER 2019

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1 36 2 37 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35



# Sustainability in the sulphur recovery industry

The increasing drive to improve and change the way we produce energy and materials and reduce greenhouse gas emissions spurs ongoing innovation. **Tobias Roelofs** and **Marco van Son** of Comprimo discuss ongoing trends in the sulphur recovery industry to meet some of these challenges and address the considerations which arise from the discussion on $SO_2$ and $CO_2$ emissions.

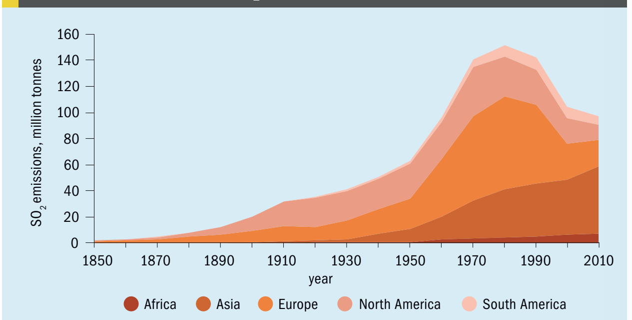
With the growing awareness of the human footprint on our environment comes the increasing drive to improve and change the way we produce energy and materials. The drive towards a circular economy is also supported by the Paris Agreement[1] in which countries and governments have committed to reducing greenhouse gas emissions. These developments spur ongoing innovation which also affects the sulphur recovery industry. The main task at hand is: Can we reduce or mitigate $SO_2$ emissions while at the same time adhere to a lower energy input and carbon footprint?

Sulphur recovery units are designed to convert highly toxic $H_2S$ into elemental sulphur which is highly important for the production of chemicals and fertilizer. In recent years there has been a trend for more stringent emission specifications with respect to unrecovered sulphur species in the form of $SO_2$. For many years the World Bank only funded projects where technologies capable of achieving less than 150 mg/Nm³ of $SO_2$ in the stack were employed[2]. With $CO_2$ starting to have a financial impact on operations via taxation and trading systems, questions can be raised such as to what extent a reduction of $SO_2$ emissions renders any benefit?

## Stringent emissions

Since the industrial revolution, mankind has been responsible for an increase in $SO_2$ emissions. Impact on the environment through the formation of acid rain increased the awareness and technology development for sulphur recovery and saw a sharp

Fig. 1: **Anthropogenic global $SO_2$ emission per continent**



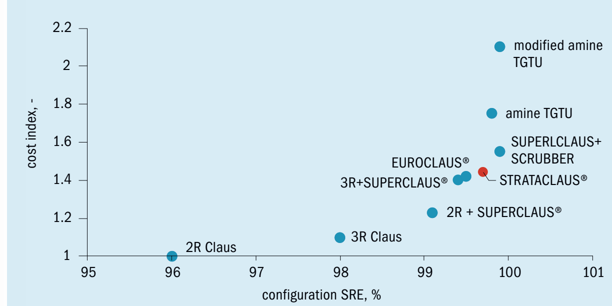

*Source: ourworldindata.org[3]*

decrease in $SO_2$ emissions from the 1970s onwards. This peak in $SO_2$ emissions is clearly seen in Fig. 1, after which the most significant reductions were achieved in North America and Europe[3]. Over time, the sulphur levels in fuel were reduced with the recent Marpol V agreement the latest step change in $SO_2$ producing fuels. The trend in $SO_2$ emission reduction clearly has not stopped as is shown by the global anthropogenic $SO_2$ emissions curve. In Asia $SO_2$ emissions are still rising, but with growing awareness of the impact of air pollution on public health[4] a peak is to be expected. Particularly in urbanised areas with emissions from transport, industry and energy production a trend towards more stringent emission regulations is apparent. This trend also drives the developments and innovations within the sulphur recovery industry.

## Technology improvements

In many jurisdictions, tail gas treatment units (TGTUs) are required to meet emission regulations. To further improve the performance of these technologies, new developments are continuously being rolled out, for example, the development of new amine solvents with increased loading or with a reduced energy demand in the TGTU as well as improved catalysts. These developments are mostly providing an economic benefit through reduced operational costs but are also examples of a reduction in energy and carbon footprint. A difference in performance level exists however when considering catalytic or amine-based TGTU options. The catalytic line-up with the highest sulphur recovery efficiency uses the selective oxidation of $H_2S$ to $S_x$ in the final reactor stage to overcome the Claus equilibrium. The SUPERCLAUS® and EUROCLAUS® processes are the top performing technologies and have been proven on large scale to be capable of meeting SRE levels of >99.6%[5]. The traditional difference in performance and costs between different technologies is shown in Fig. 2.

Fig. 2: **Cost index sulphur recovery technologies**




*Source: Comprimo*

At the 2018 Sulphur Conference in Gothenburg, a new generation of selective oxidation catalyst STRATACLAUS® was presented[6] which increases the yield in the final reactor and achieves higher performance during fluctuating operating conditions. When approaching 99.5% sulphur recovery efficiency in a catalytic SRU, a reduction of all remaining sulphur species becomes critical. The STRATACLAUS® catalyst is the first step which, in combination with ongoing developments, will result in a catalytic line-up capable of meeting 99.7% SRE on a continuous basis. This not only saves costs but also minimises the installed footprint and therewith materials, transport and construction efforts.

## Effluent streams

Effluent streams are also of interest within sulphur recovery units. Small gas streams originating from different unit operation are often routed to the thermal oxidiser as they hold no economic value for further processing apart from heat generation. In case of a flash gas from a gas treatment facility however, such a gas stream has the potential to contribute to the sulphur emissions of the plant. As the required sulphur recovery efficiency for many installations has increased over time so has the relative contribution of these streams and in some cases these gaseous effluent streams require additional processing to meet the emission regulations.

Other technologies to reduce $SO_2$ emissions such as scrubbers, produce a liquid stream which needs further processing[7]. For particular revamp situations where a reduction of $SO_2$ emissions is required, a scrubber offers economic and plot space benefit over an amine-based TGTU. Comprimo uses caustic scrubbers to reduce post-combustion $SO_2$ emissions downstream of the SRU. The formed sodium sulphate brine solution can often be handled by local water treatment facilities. Alternatively, cooling crystallisation can be employed where the formed sodium sulphate is separated as a dry product of industrial purity which can be used in e.g. the paper and pulp or detergent processes. The remaining water stream is recycled back to the scrubber reducing the water consumption of the system. This is a clear example of a waste stream that can be converted into a product stream that has a value to the client and a recycle closing the loop, thereby reducing the overall impact on the environment.

## $CO_2$ emissions – pricing and plant economics

Governments in several countries are working on systems linking the economics of plant operations to $CO_2$ emissions as a means of reaching the goals stated in the Paris Agreement[8]. A well known system in operation is the EU-ETS carbon trading system which works with a cap-and-trade system[9]. In this system the total number of emissions allowances/emissions rights is reduced yearly and companies can purchase yearly emissions rights for their operations. When exceeding the acquired emission allowances a penalty of €100 per tonne is due. As the majority of these emissions rights are auctioned, the price of emissions is balanced with the supply and demand. 2018 saw a sharp rise in $CO_2$ pricing from €7 to €21 per tonne as a result of a reducing amount of emissions allowances[10] with an expected price of €50 per tonne by 2030. This ongoing trend has already triggered changes in investment strategies[11] and forces operators to rethink their operational costs. Notable economic regions with systems in place are the EU, Canada, China, Japan and some of the states in the USA. With ongoing effort to learn from past developments it is highly likely prices of $CO_2$ will affect also refineries and gas plants worldwide.

To visualise the impact of $CO_2$ pricing on operations of a plant, the impact of $CO_2$ pricing as function of sulphur recovery efficiency was studied for a European refinery and gas plant[12]. The Net Present Value (NPV) for differences in $CO_2$ price was investigated for the following cases:

- SRE = 99.5% using a EUROCLAUS® line-up
- SRE = 99.7% using a STRATACLAUS® line-up
- SRE = 99.8% using an amine-based TGTU line-up (SCOT)

Apart from the direct pricing of $CO_2$ in the flue gas, the costs for all utilities were recalculated based on their carbon footprint and corresponding price increase. Costs for the production of catalysts and chemicals were also taken into account.

In Fig. 3 the impact of $CO_2$ pricing up to €50 per tonne on the NPV (20 years) for two SRU scenarios is shown. The impact on the refinery scenario is the lowest albeit significant at €50 per tonne. The direct costs for $CO_2$ in the flue gas accounts for 3% of the overall opex when a value of €20 per tonne is used. When the trading price is increased to €50 per tonne of $CO_2$, this number increases to 11%. As a sulphur recovery unit is typically a net energy producer (in the form of excess steam), an increase in $CO_2$ pricing will also bring about more value of this energy stream which balances with the increase in costs for electricity production. The net overall result is that the overall NPV for a typical refinery will be reduced but not significantly. The sensitivity for the different technologies with respect to $CO_2$ pricing is quite similar. Steam has a $CO_2$ equivalent value of 0.1–0.12 kg $CO_2$ per kg of steam. As all options in the refinery scenario produce





CONTENTS


SULPHUR
ISSUE 384
SEPTEMBER-OCTOBER 2019

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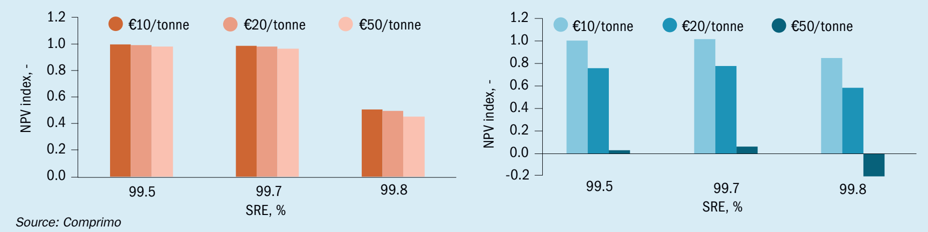
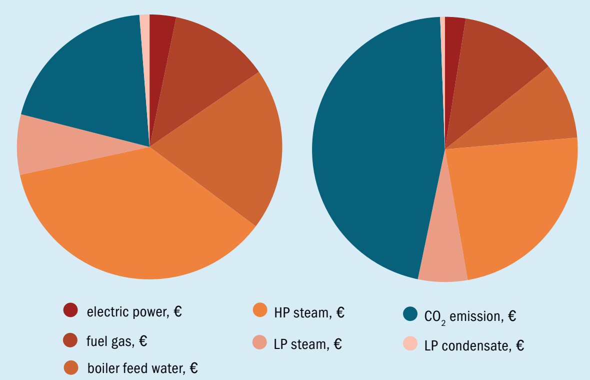
Fig. 3: **Impact of $CO_2$ pricing on NPV: *left*: 115 t/d refinery scenario and *right*: 500 t/d gas plant**




Source: Comprimo

Fig. 4: **Gas plant opex comparison for €10 (left) and €50 per tonne of $CO_2$ (right)**




Source: Comprimo

steam the sensitivity towards $CO_2$ pricing is similar.

The impact for a gas plant is far more visible and is largely determined by the $CO_2$ content of the flue gas in this scenario which are directly taxed by the $CO_2$ price. With a price of €50 per tonne a break-even point is reached when selecting a recovery efficiency of 99.5–99.7%. For the amine-based TGTU a negative NPV is obtained at the higher $CO_2$ pricing level. This is a direct result of the increased power consumption and net steam consumption required for the regenerator reboiler. At a price of €10 per tonne, the direct cost for $CO_2$ account for 20% of the opex while at €50 per tonne it rises to 46% and starts to dictate the operational costs as is shown in Fig. 4. The sensitivity of a gas plant with a higher than average $CO_2$ content in the feed is high and demands attention in the case $CO_2$ pricing is in effect.

## $SO_2$ or $CO_2$ reduction?

Slavens et al[13,14] discussed the $CO_2$ footprint of different TGTU technologies and showed that $CO_2$ emissions rise exponentially with respect to the additionally recovered $SO_2$. Again, this prompts the question: Why do we require such stringent $SO_2$ emissions specifications?

The health effects of $CO_2$ known to occur at substantial levels range from headaches and fast breathing to suffocation at high concentrations. The $CO_2$ emissions near petrochemical installations is so low that these health impacts do not occur. The main concern with $CO_2$ is its impact on the global climate, the effects of which we are experiencing.

The health impacts of particulate matter, specifically urban areas, is a topic of high interest. Sizes <2.5µm can enter the finer parts of the lungs resulting in respiratory problems and related health effects[15,16]. $SO_2$ has the potential to form particulate matter directly via reaction with other species as well as indirectly by formation of aerosols which in turn act as precursors for particulate matter. With capable technologies well established it is not hard to understand the drive towards lower $SO_2$ emissions. Regardless, one can still raise the question: What are safe levels of $SO_2$ or particulate matter caused by $SO_2$? According to the World Health Organisation a concentration of 20µg/m³ is a safe level for a 24 hour exposure[15]. The harbour of Rotterdam contains substantial petrochemical facilities close to an urban environment. Reported ground level concentrations of $SO_2$ were 3.1–4.8µm/m³ in 2018 as measured by DCMR, the official environmental protection agency for the Rijnmond area[17]. Measurements were carried out near petrochemical facilities as well as in the urban areas near roads and highways in Rotterdam. The reported values are much lower than safe exposure limits and the total ground level concentrations are still dropping as shown in Fig. 5 [18]. The 'background' $SO_2$ emissions are mainly related to North Sea shipping and external industrial activities. The industry and shipping $SO_2$ emissions are related to the local petrochemical industry and shipping activities in the harbour area itself. A lower sulphur content in shipping fuel resulted in a reduction in both the shipping $SO_2$ emissions in the harbour but also on the North Sea shown by a decrease in the background emissions. The industrial emissions have also been decreasing resulting in a net change of 60% with respect to 2005 with a total ground level $SO_2$ concentration of 5.5µg/m³.

In addition, the particle size concentration PM10, equivalent to particles smaller than 10 µm, was on average 20-24 µm/m³







SULPHUR
ISSUE 384
SEPTEMBER-OCTOBER 2019

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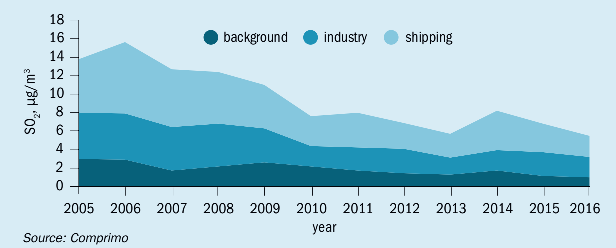
Fig. 5: **$SO_2$ emissions in the Rotterdam harbour area**




*Source: Comprimo*

which is below the advised 40 µm/m³. Some days were reported in which fine dust emissions exceeded the 50 µm/m³. As fine dust has multiple sources, the direct relationship with $SO_2$ emissions is not present here. As the understanding of direct and indirect health effects of $SO_2$ has deepened, there has been a reduction in the accepted safe exposure concentration levels. Whether additional reductions in emissions will further benefit public health is still to be determined.

In Europe, new sulphur recovery units are required to be designed to have a sulphur recovery efficiency of 99.5%[19]. The average SRE of all SRUs in the Rotterdam area is unknown but it is interesting to observe that safe levels of $SO_2$ are obtained in an urban area right next to a high concentration of petrochemical sites. If health effects are the main driver for (more) stringent $SO_2$ emissions, remote gas plants should not be required to have such high recovery efficiencies. This in turn would be beneficial for the utility and energy consumption as well as the overall carbon footprint of these facilities. Continuing with this rationale, adhering to former World Bank emission standards increases not only the financial burden on the plant owner, from an investment and operational point of view but would also induce a higher carbon footprint. Based on the currently measured ground level $SO_2$ concentrations in the presented case study, there appears to be no basis for improving $SO_2$ emissions further. Therefore, the goals set in the Paris Agreement become harder to meet with more stringent $SO_2$ emission regulations.

## Outlook

For the technology selection of sulphur recovery units, it seems there are more factors to be considered when evaluating options to reduce both $SO_2$ and $CO_2$ emissions. Simply applying the best available technology with the highest $SO_2$ recovery level or lowest $CO_2$ footprint can result in either residual $SO_2$ emissions or an increased carbon footprint. With the carbon taxation or trading systems regulatory authorities hold the key to driving the price of $CO_2$ with the aim of stimulating the development of a carbon-neutral economy. Via a case study it was shown that these developments will also affect the operational costs of sulphur recovery plants. As a result, the carbon footprint starts becoming a selection parameter in the technology selection phase.

With increasing sulphur recovery efficiency, it was shown that the carbon footprint can strongly increase when pursuing the World Bank Standards[13,14]. With the known effects of $SO_2$ on public health it is fair to say authorities would like to reduce emissions, particularly in urbanised areas. Safe levels of $SO_2$ concentrations however are met in urban areas with a large concentration of petrochemical sites, with the harbour of Rotterdam scenario provided as an example. As such, ground level concentrations in many areas adhere to the WHO standards and therefore from a carbon footprint standpoint it appears that the overall net effect on the environment is negative when a further decrease in $SO_2$ emissions is mandated. These considerations illustrate the increasing complexity in emission regulations and technology selection facing policy makers and operating companies in the years to come. ■

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SULPHUR
ISSUE 384
SEPTEMBER-OCTOBER 2019

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# Technology options for tighter emissions

Finding the best solution to reduce emissions from sulphur recovery units and tail gas treating units requires careful and detailed evalution of many factors. In this article Fluor introduces a new carbon dioxide recovery process and Siirtec Nigi, RATE and Kinetics Technology report on recent studies to identify the best technologies and processes to meet more stringent emissions regulations.

## Fluor's Oxygen Enhanced Claus $CO_2$ Recovery Process

The adverse impact of excessive $CO_2$ to the global climate is becoming more obvious every day. Regulations to reduce $CO_2$ emissions to the atmosphere from the oil, gas and chemical industry is imminent. To date, very few technologies have succeeded in being commercialised and made available to the market due to their unacceptably high capital (capex) and operating expenditure (opex) requirements. Current $CO_2$ recovery technologies for sulphur recovery units of gas plants focus on recovering the $CO_2$ from the gas effluent in the acid gas removal absorber overhead or from the Claus tail gas treating amine absorber overhead. These absorber overhead effluents usually contain $H_2S$, COS, $CS_2$, $N_2$, $H_2O$, $CO_2$ and minute amounts of other gas constituents. Recovering $CO_2$ from these gas effluents necessitates removal of all these gas constituents and is a very energy intensive process, requiring high capex and opex.

Fluor's new patent-pending Oxygen Enhanced Claus Carbon Dioxide Recovery Process (OEC²RP) technology was conceived after realising that in gas plants, when operating SRU/TGTU facilities with pure oxygen, the large amount of $CO_2$ usually present in the amine acid gas produces a gas stream from the TGTU amine absorber overhead comprising mainly $CO_2$, $H_2$ and $H_2O$. This product stream is usually directed to an incinerator prior to emitting to the atmosphere. Fluor's new technology, OEC²RP with pure oxygen Claus operation, takes this product stream through additional processing steps, converting the hydrogen to water, then removing the water to yield a product stream with over 99.5% $CO_2$. The recovered $CO_2$ could then be used for enhanced oil recovery (EOR) or other industrial applications instead of being emitted to the atmosphere.

The benefits to gas plant operators are numerous, including:

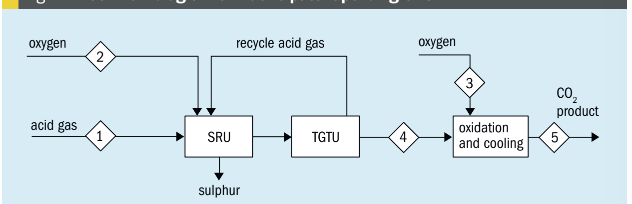
- Improved quality/environment – eliminates undesired $CO_2$ emissions to the atmosphere from huge SRU/TGTU facilities.
- Improved safety – SRU/TGTUs operating with oxygen have been proven to be much safer than Claus units operating with air as the former provides a much more stable flame in the Claus reaction furnace rendering much more stable and flexible operation; minimises undesired non-scheduled plant shutdowns and flaring of acid gases to the atmosphere.
- Reduced capital and operating costs – mitigates use of capex and opex intensive $CO_2$ recovery technologies; expands existing SRU/TGTU processing capacity without the need to build new plants and within a much shorter implementation project schedule.

### OEC²RP process description

In a conventional Claus SRU, the Claus reaction furnace operates with air to support combustion. The nitrogen content in the combustion air presents a major obstacle in recovering the $CO_2$ component. The Claus tail gas can be treated by a hydrogenation/amine unit to remove almost all the sulphur species leaving nitrogen and $CO_2$. The nitrogen becomes a challenge in recovering pure $CO_2$ and has to be treated with technologies and processes with high capex and high opex.

As shown in Fig. 1, a sulphur recovery unit operated with 100% pure oxygen or close to 100% pure oxygen (Stream 2) will convert acid gas (Stream 1) to elemental sulphur. In this case, the Claus tail gas will have no nitrogen or very little nitrogen. After treating the Claus tail gas with a hydrogenation/amine tail gas treating unit, the amine absorber overhead effluent (Stream 4) will contain three major components, $H_2$, $H_2O$ and $CO_2$ with minute amounts of $H_2S$, COS and $N_2$. The $H_2$ will be converted to $H_2O$ through oxidation with oxygen (Stream 3) resulting in a product gas containing mainly $CO_2$ and $H_2O$ with minute amounts of $SO_2$ and $N_2$. The amount of $SO_2$ will depend on the performance of the upstream CoMo hydrogenation catalyst and the amine absorber. Formulated MDEA or ExxonMobil's Flexsorb SE Plus solvent could remove most of the $H_2S$ and produce an absorber overhead effluent with very little residual $H_2S$, < 10 ppmv. The $N_2$ component comes from the impure oxygen stream and is controllable by controlling the oxygen purity going into the Claus reaction furnace. Of course, 100% oxygen would contain 0% nitrogen. An almost pure $CO_2$ stream (Stream 5) could then be recovered after a simple and cost effective cooling and dewatering step.

Fig. 1: **Block flow diagram of Fluor's patent-pending OEC²RP**




*Source: Fluor*

This game changing process mitigates the use of expensive $CO_2$ absorption/desorprtion based technologies. In addition, use of pure oxygen minimises the size of SRU/TGTU equipment, thus minimising the SRU/TGTU capex. In the case of existing SRU/TGTUs, use of oxygen effectively increases the processing capacity of the existing unit by as much as 150% of its original design capacity.

Fluor's innovation has been technically proven through extensive simulations and validations based on operating experience. One of its key components, 100% or close to 100%, oxygen SRU/TGTU operation has been proven commercially through many operating plants worldwide. The downstream oxidation step to convert the hydrogen contained in the TGTU absorber overhead consists of an incinerator (thermal or catalytic) followed by a dewatering step. Both process steps have been proven commercially.

## Siirtec Nigi tackling CO and $SO_2$ emissions in refinery SRUs

Siirtec Nigi (SN) has recently been requested by some European refineries to investigate new technical solutions to control and reduce the emissions of CO and $SO_2$ in the flue gases from sulphur recovery units. The request was dictated by new restrictions in emissions legislation.

The challenge was to reduce stack emissions as follows:

- CO down to 50-100 mg/Nm³ (at 3% $O_2$ dry basis) and
- $SO_2$ down to 10-50 ppmv (actual wet gas conditions).

A typical method to remove sulphur from hydrogen sulphide-rich gas streams from amine treating units and sour water strippers is to have a process line-up with a Claus unit, followed by a tail gas treatment (TGT) section for remaining $H_2S$ removal and finally an incineration unit.

CO is expected to be reduced in the TGT section, inside the catalytic hydrogenation reactor in particular, while $SO_2$ is typically reduced, prior to its conversion from $H_2S$, by deep absorption of $H_2S$ in the TGT absorption section with a suitable solvent.

SN took on the challenge to find technical solutions to meet the new air quality requirements for existing refineries.

### CO reduction in atmosphere emissions

In some of the refineries, the line-up included in-line heaters to heat-up process gas prior to catalytic reactors in Claus and TGT sections as well as catalytic type incinerators. Moreover, they usually experienced hydrocarbon slugs and entrainment from upstream sweetening units.

Besides suggesting the replacement of these in-line burners in the Claus and TGT sections, which accounted for about 30% of the CO and $CO_2$ content at the stack, SN identified the catalytic TGT section and the catalytic incineration section as the most critical for CO content and carried out a detailed analysis of these sections.

The situation was so demanding that substitution of the in-line burners alone did not allow the targets to be reached.

$CO_2$ and hydrocarbons in the SRU feedstock streams increase CO emissions to the stack. Proper design of the upstream sweetening unit and careful selection of a suitable amine-based solvent were therefore suggested.

In addition, several other solutions were also proposed:

### Sour shift catalyst

The greatest amount of CO in the TGT section was measured downstream of the reducing catalytic reactor, where tail gas coming from the Claus section is catalytically hydrogenated in order to reduce the oxidised sulphur species to $H_2S$. The catalyst also promotes the hydrolysis of COS and $CS_2$ and is also active for promoting the water gas shift reaction:

$$CO + H_2O = CO_2 + H_2$$

which is the primary reaction for decreasing the CO content in the process gas.

Based on SN experience, the CO value of the shift reaction at the reactor outlet is close to the thermodynamic value, however, in some of the refineries the outlet value was more than 50 times the thermodynamic value. Substitution of the catalyst alone did not allow the targets to be met. For this reason, SN investigated adding a specific sour shift catalyst to the existing one, to reduce the CO content in the tail gas and to approach the thermodynamic equilibrium at the outlet of the reducing section of the TGT.

In the end, SN identified a reducing catalyst for the TGT unit capable of limiting the CO content to 100 mg/Nm³ at the stack.

This catalyst can be located in an additional vessel downstream of the reducing reactor (under the blue vessel which represents the reducing reactor in Fig. 2) or under the existing catalytic bed inside it.

The catalyst will have to be tested in the SRU and the major drawbacks are that it requires additional space (in case it is not possible to locate the catalyst inside the reactor due to limited vessel size) and it adds additional hydraulic constraints on the system. However, SN evaluated that this solution can be considered to meet the objectives as the advantages are clear and technical problems can be easily addressed by proper engineering development.

### Catalyst oxidation in flue gas duct

An alternative solution to lower CO emissions at the stack was the installation of an oxidation catalyst in the duct connecting the incinerator to the stack (the duct is represented with a white horizontal pipe in the upper side of Fig. 3). The reaction taking place on the catalyst is as follows:

$$CO + ½O_2 \rightarrow CO_2$$

This catalyst is typically used in combined cycle power plants and also shows significant catalytic activity for low temperature hydrogen oxidation. As the tail gas delivered to the incinerator (thermal or catalytic) contains some hydrogen and the concentration can vary unexpectedly by significant amounts, further investigation was suggested in order to understand how to avoid quick temperature increases due to the unexpected oxidation of combustibles that may damage the catalyst. The maximum temperature tolerated by the catalyst is in the region of 450°C.

Due to poisoning, the catalyst can tolerate about maximum 500 ppmv of S-bearing





SULPHUR
ISSUE 384
SEPTEMBER-OCTOBER 2019

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Fig. 2: **TGT unit showing reducing reactor (blue vessel)**

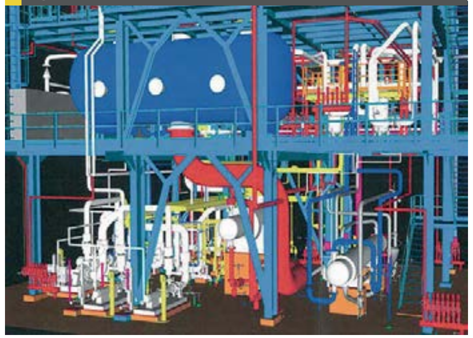

Fig. 3: **Duct work connecting the incinerator to the stack**

IMAGES: SIIRTEC NIGI

species, therefore it cannot be used in on-line ducts during TGT by-pass scenarios. In this case, suitable by-pass ducts and switching valves need to be considered in order to preserve the catalyst.

If the additional pressure drop caused by the catalyst can be tolerated by the refinery, SN identified this solution as a viable option to realistically target 50 mg/Nm³ of CO at the stack.

### Incinerator type

Another way to reduce the amount of CO is to convert existing catalytic incinerators to thermal Incinerators, in which the excess oxygen and the higher temperature (about 850°C) compared to the temperature of catalytic incinerators (about 350°C), could lead to the 50-100 mg/Nm³ value required.

Although the thermal incinerator requires a greater amount of fuel gas and combustion air compared to a catalytic incinerator, this is a referenced solution to reduce CO content and is able to achieve the required values even if not all of the other solutions are implemented.

Overall, the carbon footprint of this solution is disadvantageous, because the flue gas introduces hydrocarbons to the system and this means higher content of CO to remove, but on the flip side, this is a reliable solution to resolve the CO problem.

As the overall flue gas flow is significantly increased, special attention is required to the downstream equipment, in particular the stack and its draft.

Careful attention should be paid to the capital costs and plot implications.

All of the abovementioned solutions are feasible but the choice depends on many factors such as stream composition (in particular, hydrogen content), plot available, capital costs etc. There is no unique definitive solution and refineries were more interested in one or the other depending on their specific site requirements and constraints.

### $SO_2$ reduction in atmosphere emissions

The existing refineries were equipped with old TGTUs that they want to leave unchanged and their objective was to reduce $SO_2$ even in cases where the TGT section was off-line. This requirement was once again related to the new restriction of emissions legislation.

For this reason, instead of concentrating the studies on the utilisation of TGTUs based on formulated solvent, which could lead to the required emission levels when the TGT section is not by-passed, SN scouted the market for scrubbing systems to scrub the off-gases downstream of the incinerator section.

These systems are aimed at reducing $SO_2$ emissions to 50 ppm and should be installed with a by-pass line allowing free off-gas flow to the stack in case of scrubbing system shutdown.

The flue gas is delivered to the absorber scrubbing section where a solution is used to neutralise the $SO_2$ content of the gas.

SN analysed wet scrubbing systems using caustic soda (NaOH) and seawater (both non-regenerative systems) as they were considered the best in terms of efficiency and compliance with refineries requests, constraints and logistic advantages.

The choice of reagent to be used in this kind of package depends on several factors, the main ones being: capital investment, operating costs, utilities consumption, effluent treatment, space available to install equipment, logistics, etc.

Generally, a scrubbing system using NaOH will have a smaller capital investment, but higher operating cost.

Both NaOH and seawater scrubbing systems need rich effluent post-treatment (post-oxidation and aeration basis, etc.).

Scrubbing systems using seawater require larger availability of space to treat seawater before its discharge to the sea and the liquid circulation rate is about 10 to 20 times higher.

As an alternative, SN has also evaluated regenerative scrubber units operating on similar principles to the amine sweetening unit.

The regenerative scrubber unit consists of an absorption section where the gas is fed. $SO_2$ is absorbed from the flue gas by counter-current contact with the absorbent and then the absorbent, rich in $SO_2$, is collected in the $SO_2$ absorber sump and pumped by the rich absorbent pumps to the $SO_2$ strippers. The rich adsorbent medium is finally regenerated in a counter current way by steam generated in the reboiler.

The overhead vapour from the top of the stripper is partially condensed and separated in a reflux accumulator. The gas phase, typically 85-95 vol-% $SO_2$ saturated with water, can be recycled to the Claus section to be converted to elemental sulphur or it may be converted to sulphuric acid, by building a sulphuric acid plant downstream of the regenerative scrubber unit.

The estimated capex for this system is sensibly higher compared to a non-regenerative system and in case of recycling the $SO_2$ to the upstream Claus section, this solution represents a cost saving in terms of chemical consumption and effluent treatment.





## RATE sustainable options for reducing $SO_2$ emissions

Rameshni & Associates Technology & Engineering (RATE) recently received a request to carry out a technology comparison to evaluate its sustainable sulphur recovery processes with a view to reducing the operating costs and $SO_2$ emissions of a real operating facility (the base case), consisting of a 100 t/d SRU with an amine-based tail gas treating (TGT) unit using generic MDEA solvent. The plant used a refrigeration system due do hot weather which contributed significantly to the operating cost of several million dollars per month. The facility had a sulphur recovery efficiency (SRE) of 99.91%, achieving around 250 ppmv of $SO_2$ in the stack. Table 1 shows the different options considered. The capital cost is a Gulf Coast estimate. The utility consumptions in Table 2 are for a 100 t/d SRU/TGTU (note: negative numbers indicate consumption).

All possible cases to eliminate the refrigeration system due to hot weather and to increase the recovery with lower operating costs were evaluated. The results are shown in Table 3.

### Option 2

TG-RATE is the same as the base case (option 1) except the amine in the tail gas treating system has been changed from generic MDEA solvent to a proprietary selective solvent like TG-10, or HS-103 or Flexsorb SE. The main differences when using a selective solvent are a higher tail gas reboiler duty to strip more $H_2S$ from the rich solvent to produce more lean solvent and a higher solvent circulation rate. The emission from the incinerator stack is reduced significantly to about 50-60 ppmv of $SO_2$ dry basis and 3% excess oxygen. The selective solvent provides 10 ppmv of $H_2S$ in the absorber overhead, but with sulphur species like COS and $CS_2$ the byproduct from the reaction furnace in the SRU increases the $SO_2$ to about 50 ppmv. The hydrogenation reactor may convert some but as the effectiveness of the catalyst declines the $SO_2$ emission will increase.

In this scheme sulphur pit vent gas from the liquid sulphur degassing flows back to the reaction furnace. The pit vent gas consists of $H_2S$, $H_2O$, sulphur species, and nitrogen. When the pit vent gas is recycled to the reaction furnace, it increases the volume of gas added to the system. A detailed comparison between sending the pit vent gas to the incineration versus the reaction furnace showed about 4% capacity increase, which increases the required solvent circulation and steam flow rate to the tail gas reboiler. However, the extra flow does not have a significant impact on the equipment cost, but more steam is required.

### Option 3

TG-MAX is a new US patented process technology by RATE to increase sulphur recovery by hydrolysing additional COS and $CS_2$. The scheme is the same as the typical TGTU, except an additional reactor, the so-called hydrolysis reactor, is added after the conventional hydrogenation reactor with low temperature hydrogenation catalyst and before the quench system in the tail gas unit. In a new/grass root tail gas treating unit, the hydrogenation reactor and the hydrolysis reactor can be located in one common shell.

Based on actual operating data the amount of COS and $CS_2$ ppmv after the hydrogenation reactor is in the range of 30-40 ppmv. The hydrolysis reactor will hydrolyse the majority of the remaining COS and $CS_2$ resulting in lower $SO_2$ emission in the stack. After leaving the hydrolysis reactor the gas flows to the quench system, where additional water is condensed, and is then processed in the tail gas amine unit using formulated selective solvent to give an absorber overhead with less than 10 ppmv of $H_2S$.

Based on this scheme, the $SO_2$ emission from the stack will be around 25-30 ppmv depending on the acid gas composition to the sulphur plant and how much COS and $CS_2$ are produced and hydrolysed.

The pit vent gas from liquid sulphur degassing flows back to the reaction furnace. The location of the recycle is critical to prevent cold spots, condensation and ultimate corrosion.

In some cases, the pit vent gas is added to the combustion burner far away from the inlet air nozzle to prevent cooling the vent gas stream containing the elemental sulphur. Selecting the best injection point should be evaluated case

Table 1: **US Gulf cost estimate of RATE $SO_2$ emission schemes**

| Option | Description | $SO_2$ emission (ppm) | Capital cost million USD |
|---|---|---|---|
| 1 | Conventional TGT with MDEA solvent | 150-250 | 37.26 |
| 2 | TG-RATE: conventional TGT with selective solvent | 50-60 | 38.28 |
| 3 | TG-MAX: TGT with selective solvent + new hydrolysis reactor + recycle of pit vent gas | 25-30 | 38.66 |
| 4 | TG-Caustic: tail gas incineration + caustic scrubber | 0-10 | 40.85 |
| 5 | SETR – Super Enhanced Tail Gas Recovery | 0-5 | 40.66 |

*Source: RATE*

Table 2: **Utility consumption comparison**

| Options | Steam | BFW/Cond | Power | Cooling water (pure NaOH) | Fuel gas | Caustic |
|---|---|---|---|---|---|---|
| | kg/h | kg/h | kW | t/h | kg/h | kg/h |
| 1 | 12,402 | -13,137 | -375 | -116 | -318 | 0 |
| 2 | 10,542 | -11479 | -383 | -129 | -310 | 0 |
| 3 | 10,557 | -11,494 | -383 | -129 | -311 | 0 |
| 4 | 10,557 | -13,472 | -383 | -129 | -311 | -1.32 |
| 5 | 10,557 | -11,494 | -383 | -129 | -311 | 0 |

*Source: RATE*



CONTENTS
What's in issue 384
COVER FEATURE 1
Sulphur + Sulphuric Acid conference, Houston, Texas
COVER FEATURE 2
Sour gas projects
COVER FEATURE 3
Sustainability in sulphur recovery
COVER FEATURE 4
Sulphur enhanced fertilizers

SULPHUR
ISSUE 384
SEPTEMBER-OCTOBER 2019
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1 36
2 37
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
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22
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30
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32
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34
35



Table 3: **Options to eliminate refrigeration system and increase sulphur recovery**

| | Base case SRU/TGTU | SETR after incineration | NaOH scrubber after incineration | TG-MAX | SMAX, SMAXB direct oxidation and reduction |
|---|---|---|---|---|---|
| Refrigeration | yes | no | no | no | no |
| Sulphur recovery, % | 99.91 | 99.99 | 99.99 | 99.95 | 99.5 w/o SETR<br>99.99 w/ SETR |
| Catalysts | Al, Ti, CoMo | adsorbent, Al, Ti, CoMo | Al, Ti, CoMo | Al, Ti, CoMo, hydrolysis cat | SMAX, AM, SMAXB, Al, Ti |
| Chemical | MDEA | MDEA | MDEA, caustic | Selective solvent | - |
| Utility, steam, BFW | base | base | base | base | lower than base, no TGTU |
| Power refrigeration, MW | 200 | 0 | 0 | 0 | 0 |
| Fuel gas, Gcal/day | 6,300 | 6,300 | 6,300 | 6,300 | 6,300 |
| HP steam, export, t/d | 25,000 | 25,000 | 25,000 | 25,000 | 25,000 |

*Source: RATE*

by case to make sure the impact on the combustion temperature is minimal.

## Option 4

The majority of US refineries are requested to reduce the emissions of their existing units by adding a caustic scrubber after the incineration unit to replace the stack without making any changes to existing units. No shutdown is required to add the caustic scrubber system. With this scheme, virtually zero emission of $SO_2$ (0-10 ppm) from the tail gas incineration can be achieved.

The effluent gas from the incinerator waste heat boiler is desuperheated in a venturi scrubber by intimate contact with a 10 wt-% caustic solution. During the liquid vapour contact a portion of the $SO_2$ is removed from the vapour and the gas is cooled.

The liquid-vapour mixture then flows to the caustic scrubber. The vapour flows up through the packed bed of the caustic scrubber against a countercurrent stream of 10 wt-% caustic solution to scrub the remaining $SO_2$ from the tail gas. The treated gas leaving the caustic scrubber will contain low ppm levels of $SO_2$.

The main disadvantage of the caustic scrubber is that it generates a new waste stream (spent caustic) which contains absorbed $SO_2$ that needs to be disposed of safely or neutralised. In some facilities dealing with the spent caustic is a major issue. The spent caustic can be sent to the water treatment system if the facility has such a unit, another option is to collect the spent caustic in a tank and by bubbling air through the solution a chemical reaction takes place which neutralises the solution which can then be disposed without any violation of the environmental regulations.

## Option 5

SETR (Super Enhanced Tail gas Recovery) is a new US patent pending technology by RATE to recover $SO_2$ after incineration for cases where zero emission of $SO_2$ is requested but using a caustic scrubber or lime scrubber is not allowed, or producing spent caustic is not permitted. In this way, unrecovered sulphur species from the SRU/TGU are recovered as sulphur and not wasted. No chemicals are required and no waste stream is generated. In this scheme pit vent gas from liquid sulphur degassing flows back to the reaction furnace or to the incineration unit.

The SETR process consists of two reactors that switch between adsorption and regeneration mode. The SETR reactors can be added to any Claus type units, or to any tail gas treating units, after the tail gas incineration, before the stack.

The SETR process is not a sub dew point process it is an adsorbent process which has fixed bed reactors that require heat up and cool down. Switching valves are used to switch between hot mode and cold mode of operation.

The $SO_2$ adsorption mode operates at cold temperature. As a result, the gas leaving the cold reactor to the stack is $SO_2$ free. The cold bed SETR reactor containing adsorbed $SO_2$ then switches to a hot bed SETR reactor. To establish an adequate temperature to regenerate the adsorbed sulphur compounds, the SETR hot reactor receives a slip stream of the feed amine acid gas containing $H_2S$ plus a slip stream of air from the main combustion air blower. The regenerated stream from the hot SETR reactor is recycled back to the thermal or catalytic section of the Claus unit. Recycling this small stream does not have any impact on the existing SRU and its hydraulics. No modifications are required apart from adding a nozzle.

The SETR technology also has lower capital and operating costs compared to caustic scrubbing or any tail gas polishing unit.

Cost savings can be made if the SETR technology is added to a conventional SRU/TGU, as it would not be necessary to replace the generic solvent in the TGT unit and it would not require the sulphur pit vent gas to be recycled to the Claus unit.

### Combination of SETR with SMAX or SMAXB

In the patented process by RATE known as SMAX and SMAXB the catalytic stages consist of one or two Claus stages, a direct reduction stage and a direct oxidation stage. Both use proprietary catalysts that are offered by RATE to achieve up to 99.5% sulphur recovery. In the last condenser, the condensed sulphur is separated from the gas in a coalescer section that is integral within each condenser and





CONTENTS



SULPHUR
ISSUE 384
SEPTEMBER-OCTOBER 2019

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fitted with a stainless steel wire mesh pad to minimise sulphur entrainment. The tail gas flows to the incineration system to convert all the sulphur components to $SO_2$. The combusted products are cooled and flows to the SETR tail gas treating process.

The regenerated stream from the SETR process is recycled back to the SMAX or SMAXB process where near 100% recovery is achieved without using any conventional tail gas treating system. This scheme will reduce the capital and operating costs compared to a conventional SRU/TGU which requires much more equipment, very high utility consumption in the tail gas treating plus chemical solvent.

### Tail gas treating and sulphuric acid production

There are some refineries around the world that are able to produce sulphuric acid and have a market for it in addition to consuming it for in-house uses.

In some new sulphur projects the tail gas units have been eliminated due to the high cost to achieve near 100% sulphur recovery and a sulphuric acid plant has been installed instead to eliminate $SO_2$ emissions to the atmosphere. In new refineries the concept of using a sulphuric acid plant as the tail gas treatment allows any vent gas, or tail gas feed that contains sulphur compounds to be routed to the acid plant.

In this option, the TGT amine unit and the incineration system is completely eliminated and the tail gas from the SRU is routed to the sulphuric acid plant. The vent gas from the sulphur pit and the sulphur degassing could be routed to the front of the SRU or to the sulphuric acid plant directly. Overall sulphur recovery of nearly 100% can be achieved.

Another benefit of acid plant technology is if the refinery has to process crude with high nitrogen content. The sour water stripper ammonia gas may be beyond the capability of the sulphur plant but could be processed in the acid plant.

### Evaluation summary

This project was conducted to evaluate the additional cost to reduce emissions and to provide the available options to carry out such modifications and upgrade. The evaluation performed showed that while the cost is higher for achieving much lower emissions it is still in an acceptable range.

## KT study: impact of $SO_2$ reduction on opex and capex

KT – Kinetics Technology proposes different plant configurations and technologies for SRUs and TGTUs, incorporating innovative modifications, to meet emission limits with as little impact as possible on the operating and capital costs. Relevant studies and optimisations are carried out according to acid gas quality and $SO_2$ emission limits.

The following study compares how different process solutions for the reduction of $SO_2$ from SRU/TGTUs affect capex and opex.

The economics for three process solutions are compared, starting with a simple Claus configuration with a conventional TGT section to a configuration adopted for the most stringent $SO_2$ emissions.

Based on the same acid gas feedstock, sulphur production and utilities conditions, a sensitivity study on capex and opex has been carried out by varying only the process scheme in each case to achieve more stringent $SO_2$ emissions.

### Case A

This case can be considered the base case and refers to an SRU with a process scheme able to achieve a sulphur recovery efficiency of 99.8%, corresponding to about 1,300 mg/Nm³ of $SO_2$ in the flue gas from the stack.

A conventional scheme is foreseen:

- TGT section using 40-45 wt-% generic MDEA solution;
- lean amine loading of 0.01 mol $(H_2S+CO_2)$/mol MDEA;
- temperature of MDEA solution in the range 38-42°C;
- liquid sulphur degassing section internal to the sulphur pit with degassing air sent to the incinerator;
- atmospheric sulphur pit (or sulphur drum) with the sweep air sent to the incinerator.

### Case B

This case refers to an SRU with a process scheme able to achieve a sulphur recovery efficiency of 99.9%, corresponding to about 600 mg/Nm³ of $SO_2$ in the flue gas from the stack.

The following configuration has been considered:

- TGT section using 40-45 wt-% generic MDEA solution;
- lean amine loading of <0.01 mol $(H_2S+CO_2)$/mol MDEA;
- temperature of MDEA solution in the range 38-42°C;
- liquid sulphur degassing section external to the sulphur pit with degassing air sent to the Claus section;
- atmospheric sulphur pit (or sulphur drum) with the sweep air sent to the incinerator.

The main modification to the conventional scheme represented by Case A is the introduction of an external degassing column with the vent gases being reprocessed in the Claus unit. Besides the features listed, integration of the following is also considered:

- consumption of plant/instrument air for sulphur degassing;
- the degassing column is now a pressure vessel;
- a sulphur seal is added downstream of the degassing column;
- the combustion air to the thermal reactor is preheated with a shell-and-tube heat exchanger using LP steam, before being mixed with degassing air;
- an additional sulphur pump is considered to pump the sulphur to the degassing column.

### Case C

This case refers to an SRU with a process scheme able to achieve a sulphur recovery efficiency of approximately 99.98%, corresponding to 150 mg/Nm³ of $SO_2$ in the flue gas from the stack.

The following configuration has been considered:

- TGT section using 40-45 wt-% formulated MDEA solution;
- lean amine loading of <0.001 mol $(H_2S+CO_2)$/mol MDEA;
- temperature of MDEA solution in the range 38-42°C;
- liquid sulphur degassing section external to the sulphur pit with degassing air sent to the Claus section;
- Pressurised sulphur drum with the sweep gas (nitrogen) sent to the TGT section).

When emissions regulations are so stringent, the use of formulated amine brings significant benefits to SRU capital and operating costs:

- reduction of steam consumption compared with generic amine solution since it is more easily regenerated;
- reduction of cooling duty. The lean amine temperature can be slightly increased considering the higher efficiency of formulated amine;







SULPHUR
ISSUE 384
SEPTEMBER-OCTOBER 2019

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Table 4: **Capex/opex comparison for Cases A, B and C**

| Capex | Case A | Case B | Case C |
|---|---|---|---|
| Degassing column | yes: internal to pit (DP* = atmospheric) | yes: external to pit (DP* = 5 barg) | yes: external to pit (DP* = 5 barg) |
| Combustion air preheater | no | yes | yes |
| Undegassed liquid pumps | no | yes | yes |
| Degassing column sulphur seal | no | yes | yes |
| Sulphur drum | no | no (not strictly required, but atmospheric if used) | yes (DP* = 5 barg) |
| **Opex** | **Case A** | **Case B** | **Case C** |
| Plant/instrument air to degassing system | no | yes | yes |
| Additional LP steam to combustion air preheater | no | yes | yes |
| Additional electric power | no | yes | yes |
| Additional nitrogen consumption | no | no | yes |

**DP: Design pressure*

*Source: Kinetics Technology*

- reduction of solvent flow rate with consequent lower investment cost (smaller equipment).

The use of formulated amine is usually combined with the recycle of sweep gas to the TGT unit and consequently introduction of a sulphur drum. This solution can enhance the performance of the unit with a limited impact on operating and capital costs. However, the following integrations are also considered in addition to the scheme identified for Case B:

- nitrogen consumption for sulphur drum and increased steam consumption for ejector;
- replacement of sulphur pit with sulphur drum;
- formulated amine cost.

Table 4 summarises the main difference for estimated capex/opex for the three cases.

## Results

KT has analysed the increase of opex and capex for the different configurations described. The capital and operating costs increase with increasing complexity of the unit, however, technological improvements minimise the impact.

Fig. 5 shows the opex costs of Case B and Case C compared to the base case (Case A). The increase in operating costs is not proportional to the reduction of $SO_2$ in the flue gas when moving from Case A to Case C. The opex increases sensibly when reducing $SO_2$ emission from 1,300 mg/Nm³ to 600 (i.e. about 50% less), however, the increase of operating cost to move from Case B to Case C, with a reduction of $SO_2$ to about 25% of Case B emission, is sensibly lower. This is mainly due to the better performance of the formulated amine that is able to achieve a very lower lean loading with almost the same flow rate and steam consumption, resulting in a favourable equilibrium approach at the top of the absorber.

Fig. 6 shows how the capex, expressed as a percentage, compares to the base case (Case A). Similarly, the variation of capex is not proportional to the reduction of $SO_2$ in the flue gas to the stack, because the amine circuit design can be almost maintained as per Case B using only formulated amine instead of generic MDEA, while the sulphur drum installation has a relative impact on the final investment cost.

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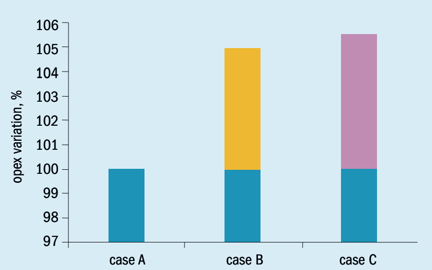
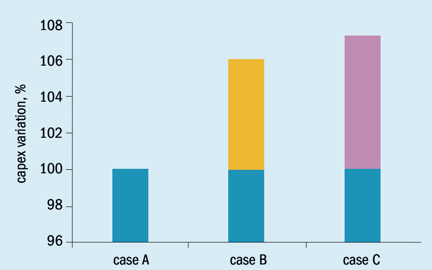
Fig. 5: **Opex comparison for three different cases**




*Source: Kinetics Technology*

Fig. 6: **Capex comparison for three different cases**




*Source: Kinetics Technology*








SULPHUR
ISSUE 384
SEPTEMBER-OCTOBER 2019



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1 36
2 37
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18
19
20
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33
34
35



# Benefitting from SRU performance tests

Beyond explaining the rigours of completing the test work, **Dharmesh Patel** of Sulfur Recovery Engineering describes what benefits a SRU performance evaluation can deliver to the operator. The advantages apply to all stakeholders of the SRU including operations, maintenance, management, and environmental personnel. From reducing emissions to extending the life of SRU catalyst, a simple performance evaluation can provide substantial insight to operators which can, in turn, save money.

Throughout the lifecycle of a sulphur recovery unit (SRU), there are a number of checks which must be made. In essence, plant operators go through the motions of replacing catalyst within a specified timeframe. The unit is then shut down, all of the catalyst within that train is replaced, and then the unit is started back up. Most operators have multiple SRU trains, allowing them to ensure that there are no losses to overall production strictly due to sulphur dioxide ($SO_2$) emissions.

That being said, there are some plant operators who have concluded that replacing catalyst on a specified time interval is very costly. Just by delaying (or extending) the life of catalyst by an extra year can prove to save a lot of money in the long-term. This fact is further exemplified for those operating multiple SRU trains. In order to extend the time period between catalyst change outs, the first determining fact is to estimate when the catalyst will require change out – when will the catalyst become deactivated. This piece of information is one of many that come out of an SRU performance evaluation.

Sulfur Recovery Engineering (SRE) is an engineering service provider to the sulphur recovery industry. SRE's mandate is to assist sulphur recovery unit (SRU) operators to achieve their recovery efficiency license requirements and to ensure that their SRUs are operating reliably and efficiently. In achieving this mandate, SRE conducts onsite sampling, analyses and operational recommendations for SRUs worldwide. The main service performed is an SRU performance evaluation.

## SRE testing services

Since 1998, SRE has been helping its clients to cut costs, reduce emissions, and optimise the performance of their acid gas removal units, sour water strippers and sulphur recovery units. Key features of SRE testing services include:

- rapid response time – SRE's testing equipment can be checked as baggage on any commercial airline allowing them to be on site within 24 hours in most cases;
- superior micro gas chromatography technology enables SRE to fully analyse a gas sample in less than five minutes;
- onsite trace ammonia analysis with immediate results eliminates long waits for results and the need for, and expense of, return site visits;
- onsite delivery of results before SRE's team leaves site enables immediate implementation of recommendations and action items;
- onsite operator training seminars delivered by the engineers who conduct the testing and troubleshooting.

## SRU performance evaluations

An SRU performance evaluation goes beyond the simple collection of interstage gas samples from the SRU and includes a comprehensive engineering evaluation of each of the different unit operations within the process. As testing of sulphur plants progressed through the 1970s and 1980s, the methodology and level of thoroughness in conducting the accurate sampling, analysis and engineering of SRUs increased. Now, a performance evaluation touches on numerous stakeholders within a gas plant or refinery.

There are various reasons as to why a performance evaluation would be completed for an SRU, based on SRE's experience, the most common being for third-party verification of the recovery efficiency as dictated by environmental regulations. Another reason is that, over time, the conditions under which the SRU is operating may be different to those considered in the original design. For example, the crude being processed by the refinery has changed to improve margins, the upstream processes have been modified to increase sulphur or nitrogen removal, or the raw gas from existing wells has changed in composition over time. As such, operators would conduct a performance evaluation in order to define the new optimal operating setpoints. Another point regularly considered, although not the last, is the evaluation of catalyst, as an evaluation of the catalyst activity is considered ahead of a turnaround to determine which converters should be replaced. Whatever the reason for conducting a performance evaluation of the SRU, there are certain steps which must be followed.

## Steps

The following steps outline SRE's procedures for conducting an SRU performance evaluation. Steps can be different from company to company. However the following is considered the gold standard in order to obtain a complete test period.





### Preparation

Extensive time and resources go into preparing for the sampling of the SRU by the onsite representative. This person is usually the engineer directly responsible for the operation of the SRU. That being the case, the results and recommendations which come out of a performance evaluation must be of high value to the operating company investing in the test period. As such, it is important that all issues faced by the operating company be presented to the evaluating company in order to devise a test period that adequately addresses all of them.

Another item which must be considered for the test period is the onsite preparations with the completion of safety considerations. Taking gas samples from the SRU involves dealing with hydrogen sulphide ($H_2S$), sulphur dioxide ($SO_2$) and/or ammonia ($NH_3$). For some operators, having such samples brought into their laboratory is against company policies. For others, testing of the SRU has never occurred (or at least not in recent memory). From that point of view, the necessary approvals and safety audits must be considered. Likewise, the company carrying out the sampling work must be accredited and have a proven safety record with regard to conducting work handling these dangerous gases.

Last is the sample point preparation. Not all SRUs are fitted with self-cleaning sampling valves (such as Strahman or Ram Seal valves), and those with gate vales are most likely plugged. Not only can sample points be plugged with solidified sulphur, they can also be plugged with sulcrete, a combination of sulphur, soot, and refractory or catalyst particles. Likewise, facilities which don't have self-cleaning valves are most likely to have these sample points inaccessible from grade or from the platform and therefore require scaffolding. As significant time can be spent making sample points accessible and clearing them for sampling, it is recommended to have these steps completed prior to the test period.

### Onsite work

Depending on the scope of work for the test period, the locations, types, and a number of samples collected would vary. At a minimum, two sample sets from each SRU should be obtained in order to demonstrate repeatability in the results. If there are compositional changes due to direct-fired reheaters or hot-gas bypasses, then additional samples beyond the usual condenser outlets must be obtained. The latter sample points are chosen because of the amount of sulphur vapour within the process stream is minimised and as such the sample point will likely not get plugged during the test period. Additionally, if there are compositional changes due to the nature of the process (e.g., the addition of oxidation air in SUPERCLAUS®, the regeneration stream in CBA or the recycle acid gas in SCOT, etc.) then extra samples must be obtained as well.

While on site, the test crew should perform visual checks on the SRU. Checking rundown lines, opening the waste heat boiler blowdown line, and verifying the main burner flame colour are a few examples. These items can be normal procedure for shift operators and having another set of eyes provides an added benefit. As indicated later, knowing these pieces of information provides the basis for troubleshooting the unit when there are upset conditions.

Last, the test crew will conduct face-to-face meetings with the relevant stakeholders and ensure that all the necessary data is collected prior to leaving the site. Should urgent changes be necessary to ensure the efficient performance of the SRU, these will be discussed during a wrap-up meeting where all analytical results and preliminary recommendations are given prior to leaving site.

### Engineering work

Once back at the main office, the simulation, calculations, and evaluation of results are then completed. In combination with the DCS data of the test period (the temperatures, flow rates, and pressures), the simulations of the SRU are converged to the analytical results (i.e., the chromatograph compositional analyses). It is from this test period specific modelling which the conclusions and recommendations can be obtained.

## Benefits

Here is the business case for the SRU performance evaluation. If done correctly with an emphasis on obtaining the most value out of the evaluation, then the operator can come out of the test period with a sound investment made into the efficiency and reliability of the SRU.

### Environmental department

The environmental team is entrusted with ensuring that the recovery efficiencies of the SRU are being verified by the third party, the most common reason for performance evaluation. As such, it is most suitable that the single most important number sourced from the performance evaluation report is the overall recovery efficiency of the SRU and/or its specific trains.

If stack samples are obtained during the test period, then evaluations on (1) the amount of fuel gas consumed by the thermal oxidiser and (2) the amount of carbon dioxide ($CO_2$) emitted can also be obtained. As environmental regulations continue to become more stringent, these values will move from being an added service to a requirement.

### SRU engineer

As the main person responsible for the SRU, the SRU Engineer is most concerned with solving the day-to-day issues faced by the unit. From this perspective, the engineer can build the business case for conducting the SRU performance evaluation based on the reliability issues or performance uncertainties which are being observed.

Some of the items from the performance evaluation report which directly impact the SRU engineer include the following:

- commentary on the feed streams to the unit including metering;
- evaluation of the main burner and destruction efficiency;
- evaluation of the reheaters;
- evaluation of the catalyst activity;
- evaluation of the condensers;
- review of the analysers and their relative accuracy.

Further, given annual performance evaluations, the engineer can then trend the performance of the unit over time to use as a reference during upset conditions or to illustrate trends in performance.

### Operations

As the gatekeepers of the SRU, plant operator personnel live within the unit and are the closest to it. If there are any reluctances with operations of the SRU, those are put aside once the company carrying out the test work arrives onsite. One of the unspoken values created by conducting regular performance evaluation is the cross-pollination while the test crew is on site performing the work. Here, operations personnel get a chance to have all their questions answered by a trusted source. Last, when performance evaluations are done on an annual basis, this benefit alone can save plant operators in training costs.

Beyond the verbal communication, the SRU performance evaluation report provides significant details as to the correct operating setpoints for the unit and provides a reference that the instrumentation is reliable and operating correctly.





SULPHUR
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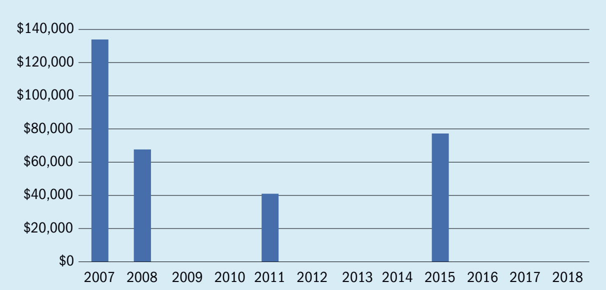
1 36 2 37 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35



Fig. 1: **South American refinery annual spend on SRE services**




*Source: Sulfur Recovery Engineering*

## Maintenance

It is a misconception that a performance evaluation only deals with the process side of the SRU. Problems highlighted by the inability to achieve the maximum practicable recovery efficiency can be related back to maintenance issues. As such, while on site, an evaluation of the chronic issues faced by the maintenance department should be evaluated.

Equipment issues are further exemplified when the evaluation company also conducts regular shutdown and start-up assistance projects in conjunction with regular performance evaluations. Through transient operation additional equipment issues can be highlighted.

The site visits, start-up and shutdown assistance and performance testing give SRE subject matter experts an opportunity to do an overall evaluation of the SRU. It could highlight the core maintenance issues and if there any updates or improvements required regarding the operational procedure, routine log sheet or if training is required for the crew to assist them to operate the plant more reliably.

Last, there is a level of preventative maintenance which occurs through regular performance evaluations. Through the production of data, the evaluation of the results and the recommendations for improved performance, maintenance can obtain the data necessary to identify issues before they impact the reliability of the SRU.

## Management

Once the test period and the detail engineering report are completed; management can plan and budget for future SRU-related expenses such as catalyst change over, possible retrofits and plant outages. A good performance evaluation report will go into detail as to what pieces of equipment need further investigation, which ones need replacement, and frame everything with consideration of the future plans of the facility.

## Case studies

To illustrate the business model for conducting regular performance evaluations, the following three case studies were presented. Although the case studies do not name the operating companies and do not outline the costs incurred or saved, these items can vary significantly from site to site and can be dependent on several different factors (e.g. proximity to equipment manufactures). The review of the added benefits to all shareholders of the operating plant above should serve as a reference to identify and then to quantify potential savings when building a business case for performance evaluations.

### Case A – South American refinery

The original scope of work was to conduct an evaluation to set operational setpoints and to benchmark the Claus plant. The 180 t/d facility had completed the installation of a SUPERCLAUS® unit, but it was left idle. Low operator knowledge and troubles with start-up of the unit by the client made them reluctant to do it on their own.

Added scope included the commissioning of the SUPERCLAUS® unit (which had been dormant since 2003), to optimise the unit and conduct operator training and technical advice throughout the whole commissioning process as well as to update, review and/or rewrite SOPs.

This operating company is located in a country without strict environmental regulations. That being said, over some time the SRU was steadily improved with the commissioning of a SUPERCLAUS® unit to improve recovery efficiency and a stack CEMS to report emissions.

Deliverables:

- onsite Claus plant optimisation;
- evaluation of the suitability for a SUPERCLAUS® start-up;
- complete SUPERCLAUS® pre-sulphiding procedure (1 week);
- delivery of operating parameters and empirical relationships for optimal performance of the Claus plant and SUPERCLAUS® Unit.

After not spending any money on benchmarking their SRU, and failing to properly train their operations team to operate the SUPERCLAUS® process, the refinery was having a lot of reliability issues and struggled to meet its online ratings.

Subsequent to the first large project, the refinery continued in its endeavour to pursue high reliability of the unit. In so doing, performance evaluations were conducted on a regular basis. Each test period contained the same objective, to benchmark the performance of the unit and to optimise its performance.

During the period of peak reliability, annual performance evaluations were completed on the SRU (Fig. 1). For this client, the recommendations provided were not the only source for the push to improve the performance of the unit. Having SRE onsite reminded all stakeholders of the nuances of the SRU in terms of operating setpoints and identification of poor performing equipment.

After the short period of high reliability, a decision was made to stop conducting annual performance evaluations of the SRU. As operations and engineering learned more about the unit, management felt that the need for evaluations, training and assistance would no longer be necessary from SRE and the refinery did not conduct any evaluations through any provider for a number of years.

To date, the unit has gone from not operating the SUPERCLAUS® portion of the converter to not operating the SRU at all.

Savings due to annual performance evaluations were:

- decreased maintenance costs;
- increased reliability of the SRU.

### Case B – Alberta, Canada gas plant

In Alberta, most gas plants are struggling with a high turndown of their SRUs. There







SULPHUR
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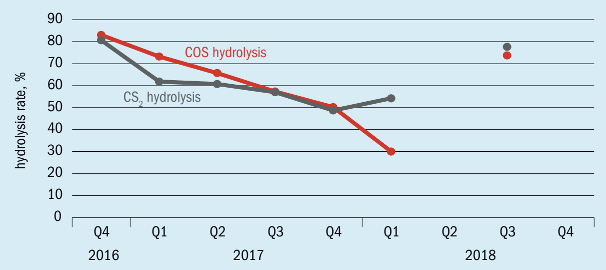
Table 1: **Determination of optimal acid gas bypass**

| Test | Fuel gas flow rate $(e^3m^3/d)$ | Acid gas bypass (%) | Reaction furnace temperature (°C) | BTEX residuals at RF outlet (mol-%) |
|---|---|---|---|---|
| 1 | 7.0 | 73 | 1,470 | 0.0029 |
| 2 | 6.0 | 71 | 1,470 | 0.0039 |
| 3 | 6.0 | 68 | 1,470 | 0.0036 |
| 4 | 4.0 | 61 | 1,470 | 0.0041 |
| 5 | 5.0 | 78 | 1,470 | 0.0043 |
| 6 | 5.0 | 79 | 1,470 | 0.0037 |
| 7 | 3.0 | 80 | 1,350 | 0.0070 |
| 8 | 3.0 | 79 | 1,350 | 0.0060 |

*Source: Sulfur Recovery Engineering*

Fig. 2: **Alberta gas plant quarterly converter 1 hydrolysis rates**




*Source: Sulfur Recovery Engineering*

is not enough sour gas for SRUs to operate within their original design. As such, plant operators have had to resort to other techniques in order to remain economical. In the case of this client, the reaction furnace was changed to become a front-side split reactor although as a gas plant they did not need to consider processing sour water stripper acid gas. The problem is their amine acid gas feed contained a lot of BTEX compounds. So, the catalyst within the first catalytic stage would get deactivated through BTEX poisoning.

The original scope of work was to determine the optimal acid gas bypass to the second zone of the reaction furnace. SRE fluctuated the fuel gas flow rate and the acid gas bypass to evaluate the maximum destruction efficiency of the reaction furnace with fuel gas co-firing (Table 1).

Upon completing the original scope, operations were concerned with what was believed to be a 'dropping off' of the overall recovery efficiency. SRE was then retained to evaluate the overall recovery efficiency while varying the acid gas bypass flow rates. Two days of comprehensive onsite testing was completed and operations were successful in maintaining steady-state operation of the SRU throughout the test period which allowed for greater accuracy in the test results. The acid gas bypass flow rate was varied from a maximum of 65% to a minimum of 60%. Test limitations were based on a recovery efficiency above 98.8% and a minimum reaction furnace temperature of 900°C. Neither of these limitations were approached during the test period which ensured that there were no emission violations or operational upsets of the SRU (Table 2).

As expected, the reaction furnace formation rates of COS and $CS_2$ in the reaction furnace increased significantly with a reduction in the acid gas bypass flow rate but was subsequently hydrolysed by the combination of the first converter and the MCRC bed in the regeneration position. This ensured that the impact on the overall recovery efficiency was negligible.

Throughout these test periods, there were residuals of BTEX components at the outlet of the reaction furnace. Additional scope was added as the client wanted to ensure that the catalyst would remain fully active until the next turnaround. Through quarterly evaluations of the first converter and the by-products of the thermal reactor, there was monitoring of the compositional analyses of various sample points over a period of time which allowed the operator to reach its turnaround without having to conduct an emergency shutdown. Fig. 2 shows the hydrolysis rates of carbonyl sulphide and carbon disulphide within the first converter which is an indicator of catalyst activity.

Table 2: **Onsite testing results**

| Test | Acid gas bypass (%) | Recovery efficiency (%) |
|---|---|---|
| 1 | 65.0 | 99.3 |
| 2 | 64.5 | 99.3 |
| 3 | 64.0 | 99.3 |
| 4 | 62.0 | 99.2 |
| 5 | 60.0 | 99.3 |

*Source: Sulfur Recovery Engineering*

In Q2 2018, the gas plant went through a turnaround in which the catalyst within the first converter was replaced and the subsequent test period illustrated the higher hydrolysis rates.

Savings due to quarterly performance evaluations were:

- trending catalyst hydrolysis rates and activity;
- ability to judge if catalyst heat soak is necessary to help with channelling;
- confirm recovery efficiency on a quarterly basis.

### Case C – European refinery

This last case study focuses on a refinery which conducts performance evaluations on a regular basis. The facility is so adamant about its testing schedule that one was conducted during a period when half of the refinery was shutdown. During normal circumstances, conducting a performance evaluation outside of normal operation is not recommended because the performance recommendations would be based on a non-typical scenario.

However, completing the test period under the semi-shutdown scenario highlighted numerous issues with the upstream amine and sour water units. These pieces of information came out of the compositional analyses of the feed streams. Thus, providing excellent value to the plant operator.







What can be inferred from the tables above are that the absorbers that were offline during the 2018 test period were the contributors of the high ammonia content within the amine acid gas. Additionally, the absorbers which were online during the 2018 test period were the contributors of the high hydrocarbon carryover to the SRU. Thus, the historical data shed light on the upstream operational issues.

Savings due to conducting annual performance evaluations were:

- time is allotted each year for the work to be completed;
- if the refinery is partially shut down, data from the previous year can be used to make up for missing data;
- conducting analysis during the partial-shutdown highlighted issues within the upstream amine and sour water systems.

Concluding, SRU performance evaluations can provide an array of value-added benefits to various stakeholders within the operating facility. Following the guide presented above will ensure that the operating facility gets the most out of a performance evaluation. ■

Table 3: **European refinery annual acid gas composition**

| Compound | 2015 acid gas | 2017 acid gas | 2018 acid gas |
|---|---|---|---|
| $H_2S$ | 87.7293 | 77.0300 | 70.7578 |
| $NH_3$ | - | 3.080 | 0.0474 |
| C1 | 0.0939 | 0.0903 | 0.1397 |
| C2 – C6+ (C1 basis) | 0.6784 | 2.4297 | 4.8221 |
| BTEX | 0.0746 | 0.0326 | 0.0495 |
| RxSH | 0.0639 | 0.0117 | 0.1129 |

*Source: Sulfur Recovery Engineering*

Table 4: **European refinery annual sour water stripper acid gas composition**

| Compound | 2015 SWS acid gas | 2017 SWS acid gas | 2018 SWS acid gas |
|---|---|---|---|
| $H_2S$ | 50.1895 | 49.3226 | 27.6166 |
| $NH_3$ | 48.9679 | 49.0551 | 62.1762 |
| C1 | 0.0249 | 0.0800 | 0.0397 |
| C2 – C6+ (C1 basis) | 0.5859 | 2.5157 | 4.0807 |
| BTEX | 0.0531 | 0.2147 | 0.1788 |
| RxSH | 0.1786 | 0.0453 | 0.0828 |

*Source: Sulfur Recovery Engineering*









SULPHUR
ISSUE 384
SEPTEMBER-OCTOBER 2019

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*Maize crop in Siaya Kenya, 9 weeks after planting (2018 Shell Thiogro Urea-ES/Special-S Field Trial).*

PHOTO: INTERNATIONAL PLANT NUTRITION INSTITUTE

# Enhancing urea with sulphur

Shell Thiogro Technologies are changing the way the fertilizer industry thinks about elemental sulphur, as agronomist **Dr Kent Martin** explains. Two innovative technologies from the company, *Urea-ES* and *Special-S*, are helping fertilizer producers diversify their product portfolios. Both products provide farmers with a flexible source of sulphur fertilizer and are well-suited to a wide variety of growing conditions and crop requirements.

## More from less

The fertilizer industry is responding to the sustainable intensification of agriculture, and the need to get more from less in particular. Greater awareness of the need for nutrient stewardship, plus the rise of precision agriculture, are changing how farmers around the globe choose and think about their fertilizer inputs. With an increasingly competitive operating environment, leading fertilizer producers are also recognising that having a diverse product portfolio is no longer just a luxury but instead is becoming essential for their future relevance and success.

By combining elemental sulphur with nitrogen, Shell Thiogro's latest suite of technologies enables fertilizer producers around the world to offer farmers a flexible source of sulphur – one that can be applied at the right rate and is well-suited to a wide variety of soils, growing conditions and crop requirements.

## Shell Thiogro technologies

Having successfully commercialised and patented sulphur technology for ammoniated phosphates in the early 2000s, Shell began to develop new processes able to incorporate elemental sulphur in urea-based fertilizers. Urea is an excellent carrier for sulphur and – as the world's most widely-applied fertilizer – has the potential to offer many more growers access to much-needed sulphur.

Shell's efforts culminated in the introduction of *Urea-ES* to the market in 2016. This innovative Thiogro technology suspends 7-20 percent elemental sulphur in a urea matrix with a nitrogen content of 43-37 percent. Shell subsequently introduced *Special-S* shortly afterwards in 2017. This technology produces a high sulphur product that is co-granulated with urea (11-0-0-75ES).

## Sulphur: the fourth crop nutrient

Alongside nitrogen, phosphorus, potassium, magnesium and calcium, sulphur is one of the six major nutrients considered essential for plant growth. Indeed, sulphur – complementing nitrogen, phosphorus and potassium – has been called 'the fourth crop nutrient'.

Most crops require an application of 15 to 30 kilograms of sulphur per hectare. Some crops, such as oilseed rape (canola) require even more.







Sulphur is one of the main building blocks of two amino acids, cysteine and methionine. As such, sulphur contributes to several critical aspects of plant development including:

- protein, enzyme and chlorophyll synthesis;
- oil content in seeds;
- nutritional quality of forages.

Unsurprisingly, therefore, soil sulphur deficiency can result in sub-optimal crop yields and poor crop quality. Sulphur-deficient crops are typically characterised by lower quality protein, lower oil and protein content, and lower nutritional quality, for example.

Today, many soils across the globe are becoming increasingly sulphur-deficient. It is also estimated that only half of the sulphur requirement of crops is currently being met through sulphur fertilizer applications. This leaves significant soil deficits and unmet demand for sulphur that still needs to be addressed. It is also anticipated that soil sulphur deficits will continue to grow due to the following factors:

- cleaner low-sulphur fuels resulting in less atmospheric deposition;
- prevalence of high-analysis fertilizers with much lower sulphur contents than their lower-analysis predecessors such as single superphosphate (SSP);
- higher yielding crop varieties removing more and more sulphur from soils.

In many parts of the world, therefore, fertilizer producers will need to offer sulphur-enriched products as part of their portfolios – in order to address growing soil deficiencies and truly enable farmers to maximise crop yields.

## Traditional sulphur sources

Two main types of sulphur fertilizer are currently available and applied to combat soil sulphur deficiency: (1) sulphate-based fertilizers and (2) fertilizers that incorporate elemental sulphur. Both types have contrasting benefits and drawbacks.

Advantageously, sulphate-based products – because sulphate is plant-available – offer crops an immediate supply of sulphur early in the growing season. However, sulphate is also highly mobile in soils, due to its water solubility, making it susceptible to leaching in coarse-textured (sandy) soils and/or during high rainfall and under irrigated conditions. Because of these characteristics, sulphate-based fertilizers may only offer a short-lived supply of sulphur and may no longer be available by the end of the growing season.

Elemental sulphur, on the other hand, is not immediately available for plant uptake, as it needs to be oxidised by soil bacteria into sulphate to become plant-available. However, this does have the advantage of offering a slower and longer pattern of sulphur release. Also, because elemental sulphur is not water-soluble, it is not leached away under wet conditions and therefore continues to release sulphur to plants during the entire growing season.

However, the historical challenge with elemental sulphur has been trying to ensure that the sulphur applied becomes available when crops actually need it. To compensate for its slower release behaviour, fall application and/or over application are commonly practiced with elemental sulphur sources. Practices such as over application, while an effective mitigation strategy that ensures nutrient availability, do typically incur additional costs. The oxidation rate of elemental sulphur can also be increased by grinding it into a very fine dust. However, this has its own drawbacks as tiny sulphur particles readily develop an electrostatic charge, potentially creating explosion and safety risks.

## Improving elemental sulphur availability

Technology holds the key to improving the plant availability of elemental sulphur. The particle size of elemental sulphur has a direct impact on the rate of oxidation, with smaller particles oxidising into sulphate faster than larger particles due to their higher surface area (Table 1).

Both *Urea-ES* and *Special-S* include Shell Thiogro's patented micronisation process for elemental sulphur. This process produces elemental sulphur particles with an average size of around 30 microns. This significantly improves the oxidation rate of the elemental sulphur in products produced using Thiogro technology versus traditional elemental sulphur sources whose particle size is typically >100 microns at minimum.

The unique technology used to produce these products translates into better field performance. The sulphur particles in products produced using Thiogro technology have a range of sizes, with some smaller and some larger than the 30 micron average. This broad size distribution is valuable as some particles will oxidise faster than others in the soil. This allows sulphur to gradually becomes plant-available over time, mirroring and mimicking the uptake requirements of crops. Products produced with Thiogro technology are therefore able to combine some of the near-term availability of sulphate-based products – without the substantial leaching losses – with longer-term sulphur availability throughout the crop cycle.

Table 1: **Impact of sulphur particle size on oxidation rates**

| Particle size (microns) | % S oxidised 2 weeks | % S oxidised 4 weeks |
|---|---|---|
| >2,000 | 1 | 2 |
| 840-2,000 | 2 | 5 |
| 420-840 | 5 | 14 |
| 180-420 | 15 | 36 |
| 125-180 | 36 | 68 |
| 90-125 | 61 | 81 |
| 60 | 80 | 82 |

*Source: canola.okstate.edu*

Shell wanted to improve its understanding and fully demonstrate the effects of elemental sulphur micronization on both sulphur availability and crop yields. The company therefore commissioned more than 50 agronomic field trials across North America, Latin America and Africa over a several year period.

In these trials, average crop yields with *Urea-ES* and *Special-S* were equal to or greater than ammonium sulphate yields and consistently higher than sulphur-bentonite yields. Overall, the results demonstrated that both *Urea-ES* and *Special-S* are commercially-competitive as an agronomic source of sulphur for crops (see Figs 1 and 2). Importantly, the reduced risk of sulphate losses partly contributed to the greater yields achieved by Thiogro produced products in several trial results.

## Higher nutrient content equals lower logistic costs

In addition to the agronomic benefits of its elemental sulphur products, these co-granulated fertilizers typically contain more nutrients than the traditional sulphur product alternatives. The 86 percent nutrient content of *Special-S* (11-0-0-75ES), for example, compares to the 45 percent nutrient content of ammonium sulphate (21-0-0-24S). Growers choosing to meet







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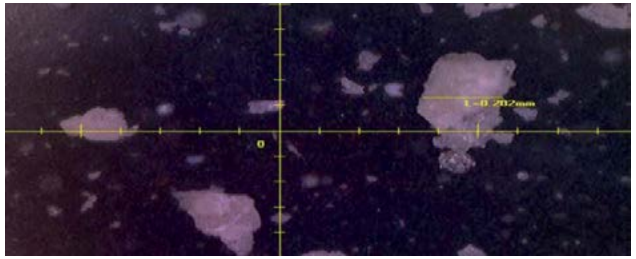


PHOTO: SHELL

*Digital microscope image of sulphur bentonite (0-0-0-90ES) showing particle size of >100 microns.*

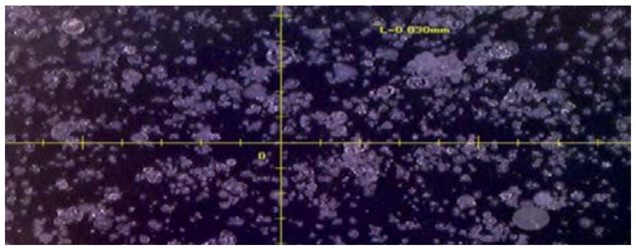
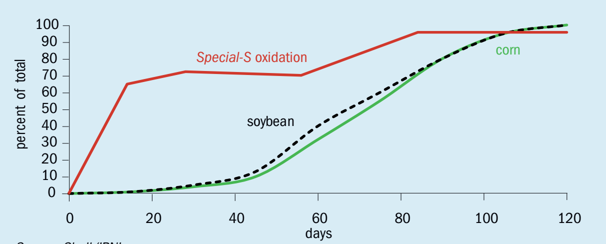


PHOTO: SHELL

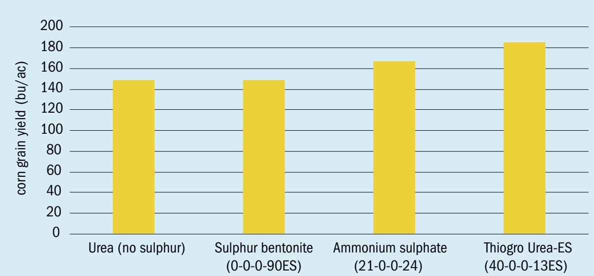
*Digital microscope image of Special-S (11-0-0-75ES) showing average particle size of 30 microns.*

**Fig. 1: *Special-S*: sulphur oxidation and sulphur crop uptake versus time**




*Source: Shell/IPNI*

**Fig. 2: 2018 corn yield trial results for an irrigated field in Missouri: *Urea-ES* versus other products**




*Source: Shell*

their sulphur requirements using *Special-S* will still be able to apply less finished product (kg/ha), even when taking into account additional nitrogen requirements. Higher nutrient content equates to lower application rates, also providing the farmer with an application cost saving. Efficiency gains at farm level, from using less product to achieve the same results, will also translate into savings further up the supply chain as a result of lower product shipment and storage costs.

## Technology partnerships

Shell has successfully collaborated with both thyssenkrupp and IPCO, leading industry providers of fluid bed granulation and the *Rotoform* fertilizer finishing process. These partnerships have ensured that *Urea-ES* and *Special-S* technologies are accessible to a wide range of fertilizer producers looking to diversify their product portfolios with high-performing and nutrient-dense sulphur-enhanced fertilizers.

## tkFT fluid bed granulation

Shell and tkFT (thyssenkrupp Fertilizer Technology GmbH) began collaborating on the fluid bed granulation of *Urea-ES* in 2015. Two teams from both companies worked together to determine the modifications required to incorporate *Urea-ES* technology into the fluid bed granulation process. Ultimately, only limited modifications were necessary, due to the flexibility of the fluid bed granulation process, requiring the installation of just a few pieces of equipment, including:

- *ThioMill* sulphur dispersion unit;
- *ThioAdd* feed additive system;
- small recycle evaporation;
- upstream sulphur feed system.

Once the initial design work was finalised, the teams switched their attention to modifications to tkFT's pilot plant in Leuna, Germany, enabling it to produce granular sulphur-enhanced urea products. These efforts ultimately resulted in a successful pilot plant trial in February 2016. Several formulations of sulphur-enhanced urea were produced (pictured) during subsequent plant runs. Valuably, the completed test runs generated more than five tonnes of products for agronomic testing.

The *Urea-ES* granules obtained have the same or better physical properties as standard urea granules in terms of:







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ISSUE 384
SEPTEMBER-OCTOBER 2019

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Thiogro Urea-ES installation at tkFT pilot plant in Dortmund Germany.

PHOTO: TKFT

- size distribution (equal);
- hardness (higher);
- bulk density (higher);
- storage (equal);
- dust abrasion (lower).

These properties allow *Urea-ES* granules to be transported, stored and applied in exactly the same way as standard urea granules. If required, the *Urea-ES* granules also can be produced with a proprietary formaldehyde-free granulation additive offered by tkFT.

The fluid bed granulation process developed by Shell and tkFT is suitable for producing different grades of *Urea-ES* with an elemental sulphur content in the 7-20 percent range. The technology is well-suited to urea producers who have access to sulphur and would like to expand their product offering and optimise their production assets (*Nitrogen+Syngas* 358, p48).

## IPCO *Rotoform* technology

IPCO and Shell Thiogro joined forces in 2016, building on many years of combined sulphur solidification experience. The aim was to integrate Shell's unique and innovative *Urea-ES* and *Special-S* products with IPCO's versatile *Rotoform* fertilizer finishing technology. This concept was successfully demonstrated during a series of continuous plant trials at IPCO's productivity centre in Fellbach, Germany. The trials confirmed that it was possible to produce granules (pastilles) of *Special-S* using IPCO's *Rotoform* process. These uniform-sized pastilles contain a large proportion (up to 75 percent) of finely-dispersed elemental sulphur in a urea matrix.

The pastilles are produced by an IPCO *Rotoform* unit from a homogeneous molten urea/sulphur emulsion feed. The *Rotoform* unit deposits the emulsion as 2-4 mm diameter droplets across the width of a steel belt cooler. Cooling water is sprayed onto the underside of this moving solid steel belt. This is highly effective at absorbing heat while also ensuring that no cross-contamination occurs between the product and cooling water. The liquid droplets eventually solidify into pastilles as they are conveyed along the steel belt. The final solid product is collected at the end of the belt and then sent to the downstream handling system – conveying, storage silo, bagging, etc.

H Sulphur Corp, one of Asia's leading sulphur suppliers and sulphur bentonite producers, has licensed *Special-S* technology and commissioned the first ever production facility in South Korea in February. In doing so, the company has fully realised the powerful potential of Shell Thiogro technology, both in terms of expanding its customer offering and limiting its exposure to commodity-based products.

Urea-ES produced at tkFT pilot plant.

PHOTO: TKFT

H Sulphur has already begun manufacturing and selling *Special-S* under its own *Super S* brand name. This product has been successfully sold and shipped to customers in Canada and Australia and Brazil, where it is being applied by farmers this season. ■

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PHOTO: H SULPHUR

PHOTO: H SULPHUR

Shell Thiogro and H Sulphur Team at newly commissioned Special-S plant in Ulsan, South Korea.







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