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SULPHUR

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Refinery SO_2 emissions
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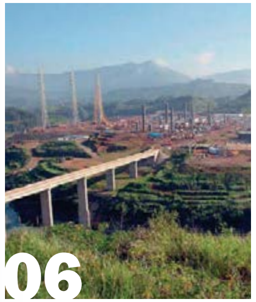
Cover: *Oil refinery flare stack.*
elgol / iStockphoto.com



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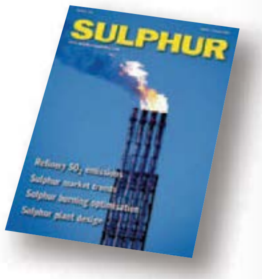
Are carbon co-polymers the future of sulphur?



> "We may only be at the tip of the iceberg of what sulphur co-polymers may be able to do.

Sulphur is, as long-term readers of this magazine are probably only too well aware, a unique material in terms of many of its properties. So unique, indeed, that some have compared it to carbon in terms of the variety of its chemistry. And that connection is coming a step closer with pronounced new interest in polymeric forms of sulphur.

Most conventional plastics, and indeed most natural fibres and organic materials, are made from long carbon skeletons. Sulphur has already had a role in modifying these via the vulcanisation process, developed by Goodyear in the 1840s, which joins the long carbon chains with sulphur bridges and increases the natural material's durability and tensile strength. Now the shoe is on the other foot, however. Under the right conditions, sulphur – usually an eight-membered ring structure – can be broken into eight atom chains which can then join together to form long sulphur chains. These long chains of sulphur can be joined together to create a solid plastic by cross-linking with carbon atoms in a process which is dubbed by analogy 'reverse vulcanisation'. Recent research by the University of Arizona has shown that the polymers can be customised via the process and mix of carbon used to suit a wide range of applications, simply by heating carbon and molten sulphur together at 185°C, without the need for a catalyst. Nanoparticles can also be added to the mix to give the end plastic the required properties. The polymers formed can be moulded into a variety of shapes, and astonishing detail is possible. By varying the organic content, the researchers say, the polymers can produce hard, glass-like plastics, or tacky, malleable substances which have potential as adhesives.

This physical tuneability has recently led to their use as a cathode material for the new generation of lithium-sulphur batteries that are being developed, as we reported in the previous issue (*Sulphur* 361, Nov/Dec 2015, pp19-21). Some sulphur polymers also reveal remarkable optical properties, assuming a native transparent, ruby-red colour.

NASA has become interested in the sulphur-carbon copolymers as a potential building material for Martian shelters, as both sulphur and carbon are readily available on the surface of Mars, reducing the payload required to carry astronauts out there. In a recent challenge to 3D print a habitat for the Martian surface, a team led by associate professor Gianluca Cusatis of Northwestern University's McCormick School of Engineering used a sulphur concrete made from gravel aggregate and molten sulphur as a binding agent. The material developed by Cusatis' team was more than twice as strong as typical sulphur concretes, which the team attributed to the fine particles of the Martian soil. When adjusted for Martian gravity, it would be as strong as concrete used for Earth skyscrapers.

All of these applications – from batteries to space engineering – are so far very niche areas. But the Arizona researchers say that we may only be at the tip of the iceberg of what sulphur co-polymers may be able to do, as they continue to characterise the various combinations of S and C. If so, it might be an intriguing solution to the perennial problem of what to do with excess sulphur, especially in an era that is processing more sour gas than ever. Sulphur producers and handlers have become used to regarding mixtures of carbon and sulphur – from dirty or contaminated sulphur to black carsuls – as a waste problem to be dealt with, but the current research is indicating that in future they may even be an opportunity.

Richard Hands, Editor

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MARKET INSIGHT

Meena Chauhan, Research Manager, Integer Research (in partnership with ICIS) assesses price trends and the market outlook for sulphur.

SULPHUR

Bearish mood

The global sulphur market has had a sluggish start to the New Year. Following the upward push from Middle Eastern producers at the end of 2015, buyers in key markets retreated to the sidelines. The seasonal holiday period also slowed trade. Sulphur demand through 2015 fell short of expectations overall as the bearish downstream processed phosphate market and slump in commodity prices took its toll. Major consumers OCP/Morocco and Mosaic/US cut production in the light of weaker end product markets. In the first half of January, little interest was seen in China or other key markets including Morocco and India, stalling developments.

Middle East producers dropped prices for January monthly contracts, a reflection of the weaker outlook. However, Tasweeq/Qatar's price of $119/tonne f.o.b. Ras Laffan and Adnoc/UAE's price of $122/tonne f.o.b. Ruwais were widely received with scepticism in the market. Aramco Trading meanwhile posted $115/tonne f.o.b. for February, signalling we are entering a period of lower prices. However, industry sources suggest the price drops from producers have not captured the full extent of the weaker sentiment as c.fr prices in China dropped below the Middle East f.o.b. range. The next tender in the Middle East is expected to test the export price level in Tasweeq's 19 January tender for 35,000 tonnes of sulphur for February loading and will likely influence the next round of monthly price postings.

Contract negotiations have been a major focus in the market, with discussions between North African buyers and producers stalling. The uncertainty in the market appeared to be the main issue, with spot prices dropping significantly in China. Both OCP, Morocco and GCT, Tunisia were still in talks in mid January. Q4 2015 contracts were settled in the $112-128/tonne c.fr range. Increased supply from the UAE in 2016 from the Shah gas project will be a consideration in discussions as ADNOC will be placing this under contract rather than in the spot market. New supply is also due online this year in Qatar, from the two phases of the Barzan project, potentially adding around 800,000 t/a of sulphur capacity to the export market. Meanwhile ADNOC was heard settling Q1 2016 contracts with end users in the mid-$120s/tonne c.fr and high-$110s/tonne f.o.b. Ruwais with traders.

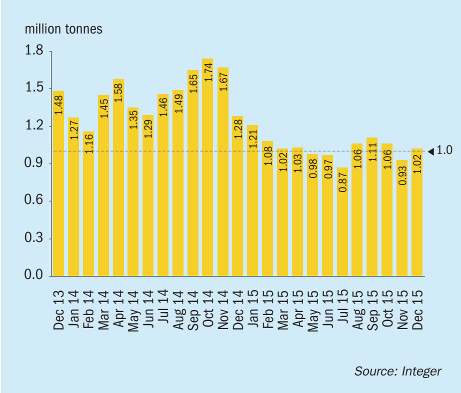
On the demand side, JPMC/Jordan closed a purchase tender for 40,000 tonnes of sulphur on 14 January for February arrival to Aqaba. According to some traders, the buyer is fully covered for the year through agreed contract volumes and the tender was simply a price checking exercise.

In Brazil, Vale is expected to consume less sulphur in 2016, due to the pressure from the downstream phosphates market weighing on its outlook. The devaluation of the Brazilian Real has also been a bearish factor for the market. Contracts for Q1 2016 in Brazil for Vale were heard settling at $122/tonne c.fr, but discussions were ongoing with some suppliers.

In the domestic European market, contract discussions for Q1 2016 centred around a potential rollover before the seasonal break but end users were looking to international developments and the weak macro economic conditions to push for a downward correction in mid January.

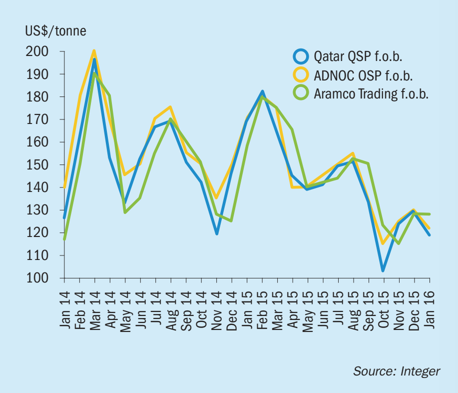
Spot prices in China were heard as low as $110/tonne c.fr for crushed sulphur in mid-January, with offers up to $125/t c.fr. However, the range was disputed due to the lack of interest and limited confirmed deals. Many buyers remained on the sidelines for much of the month in import business as local prices for sulphur were considered more attractive. The slow fertilizer market led to some processed phosphates producers moving into turnaround, further slowing activity and market interest. Inventory levels at key plants were heard to be healthy, adding to the bearish tone. There is speculation of renewed interest emerging ahead of the Chinese New Year holiday period, although this could be tempered by developments in the phosphates

Fig 1: **Chinese port sulphur inventory** Dec 2013 – Dec 2015



Source: Integer

Fig 2: **Middle East sulphur prices** Jan 2014 – Jan 2016



Source: Integer

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market. Stocks at the nine major ports in China totalled 1 million tonnes in January, a level expected to be maintained in the months ahead.

Over in India prices also softened in parallel with trends in China as well as pedestrian domestic demand moving into 2016. Major buyers were heard covered in January by scheduled contract shipments. One buyer, CIL, issued a purchase tender for around 25,000 tonnes for February arrival. The market was expecting to see a low price in the tender due to the absence of interest from other end users. FACT is due to hold a planned turnaround in Cochin in March, and has ample sulphur inventories in the interim to cover its requirements. The buyer is likely to enter the market following the turnaround in April. IFFCO purchased 35,000 tonnes of sulphur at the end of 2015 in the spot market and remains covered until May. Prices in India were heard around $125-130/t c.fr on a notional basis in January.

The continued erosion of oil prices has impacted sulphur production in the US as well as the outlook for growth in oil sands based sulphur from Canada. While refinery utilization rates have remained healthy in the US the switch over to sweeter crudes has led to a drop in recovered sulphur output in many areas through 2015. With the outlook for oil pricing remaining bleak for 2016, Integer is forecasting a flat year for sulphur production in the US in its base case scenario and has revised its outlook for production from Canada.

SULPHURIC ACID

Commodity slump

The continued collapse of global commodity pricing, including copper, zinc and nickel continues to weigh on the outlook for sulphuric acid. Contract discussions in NW Europe were continuing in mid January for Q1 and H1 2016, with rollovers expected by sellers. End users are pointing to the weaker sentiment in the international market and well as the drop in sulphur as signals for potential decreases however. Low prices remain a key feature of the NW European export market, though netbacks were holding in the single digits in January as producers remained unwilling to accept negative f.o.b. prices.

Sulphur-based acid prices in the Mediterranean region were heard around $38/tonne f.o.b.. OCP/Morocco has remained active in the market, with arrivals reflecting its regular contract shipments as well as spot cargoes. For the month of January, over 50,000 tonnes of acid were expected to arrive for the buyer, with OCP heard covered through until March. Prices in North Africa were heard in the $20s/t c.fr.

In North East Asia, discussions for Q1 2016 contracts have been underway. South Korean producers have advanced talks in China, with some agreements heard concluded at $18-20/tonne c.fr, reflecting netbacks of $1-3/t f.o.b.. Over in Japan, sulphuric acid exports dipped by 50% in November 2015, down to just 96,000 tonnes. This came on the back of Pan Pacific Copper's scheduled maintenance at its Saganoseki smelter in October-December 2015. Through 2H 2015, a price difference was seen between North West Europe export prices and North East Asia exports, partly due to the more balanced market seen in Japan and Korea, due to the turnarounds and regular shipments to China.

After a protracted period of discussions, Chilean contracts for 2016 have been confirmed. The price range has moved down as expected to $50-58/tonne CFR Mejillones, reflecting a decrease of $27-28 compared to 2015. This is the lowest price agreement since 2010, when prices were at $35-45/t c.fr Mejillones and is a reflection of the bearish market sentiment. Demand for acid has continued to be lower in 2015, with imports in October at 158,404 tonnes compared to 161,754 tonnes in October 2014. Integer continues to forecast lower imports in the coming year for Chile.

Over in Brazil, a number of cargoes were agreed at the end of 2015 for January shipment. In Petrobras' tender for 8,000-15,000, an award was made at $35/tonne c.fr for mid-December to mid-January arrival. Mosaic also secured 9,000 tonnes. Yara agreed an 18,000 tonne cargo which was heard priced at $40-45/tonne c.fr. Timac also expressed interest for 10,000 tonnes for mid-January arrival, but a deal was not heard concluded. Continued demand from Brazil will be crucial in the months ahead as an outlet for key suppliers and to support acid pricing. ■

Price indications

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

Cash equivalent	**July**	**August**	**September**	**October**	**November**
Sulphur, bulk ($/t)					
Vancouver f.o.b. spot	145-155	144	115	105-115	120-125
Adnoc monthly contract	155	135	115	125	130
China c.fr spot	150-168	140	118	110-138	125-145
Liquid sulphur ($/t)					
Tampa f.o.b. contract	137	137	137	110	110
NW Europe c.fr	170-200	185	185	153-185	153-185
Sulphuric acid ($/t)					
US Gulf spot	70-80	68	60	45-55	40-50

Source: CRU

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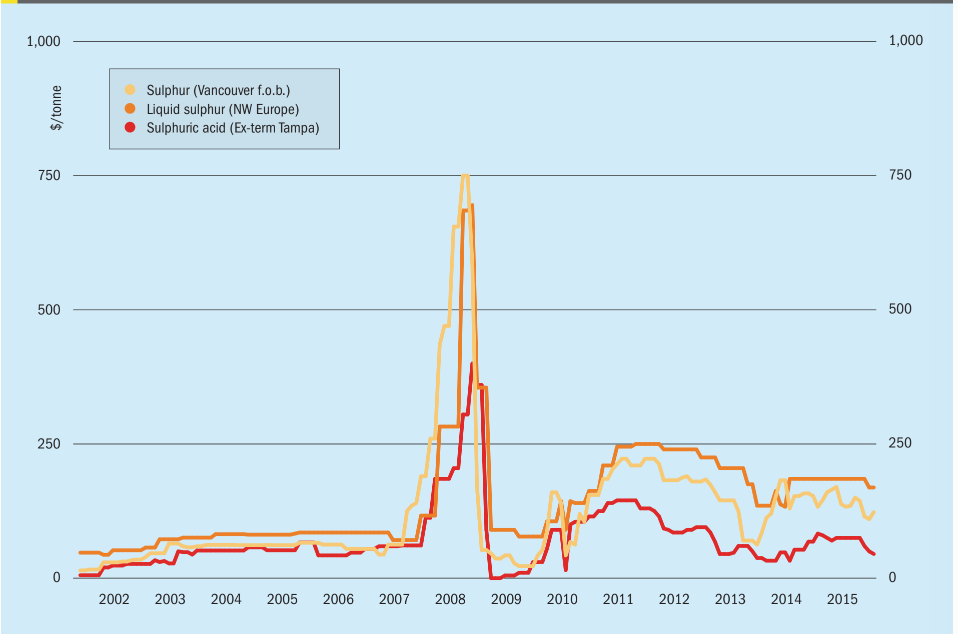
Historical price trends $/tonne



Source: BCInsight

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- Prices are likely to drop further before stabilising and potentially recovering later in Q1 2016. China remains the wild card, with an uptick in trade expected to help improve the market. However, further price erosion is likely before stimulating significant interest in import volumes.
- Middle East export volumes will be a focus point for the next 12 months, as Shah continues to ramp up as well as Qatar's Barzan project adding additional volumes in 2016.
- The bearish outlook for oil prices in 2016 will continue to weigh on US recovered sulphur. Further delays to oil sands and oil refinery projects will add to the more conservative outlook for supply from North America.
- Indian buyers report good stocks and buying interest may be subdued for the coming months.
- The start up of Mosaic's melter in Tampa, Florida is likely to lead to increased availability from Vancouver to offshore markets in 2016. However, railed volumes to the US may offset the decrease from US domestic refineries.
- Planned leaching projects may face delays during this period of low metals pricing and impact the outlook for sulphur demand growth.
- **Outlook:** Prices to weaken in key markets such as China and India, before stabilising during Q1 2016. The processed phosphates market may support sulphur in the spring, as expectations fell short in 2015, with a recovery anticipated from the market this year. Overall, average sulphur prices likely to remain in a similar range to 2015 levels for the next few months.

SULPHURIC ACID

- Spot prices in Chile likely to remain under pressure due to low contract price settlements as well as ample supply in the region.
- NW European exporters may look to diversify markets in preparation for the start up of Sherritt's Cuba sulphur burner.
- Brazil to remain a key outlet for producers as a key source of spot purchases, supporting the market in the short term outlook.
- The outlook for domestic acid production in China is expected to continue to rise but has been revised down due to the low price outlook for metals.
- US contracts have been agreed in the \$85-150/st c.fr Southern US range for 2016, up \$10/st at the low end compared to 2015 as the market showed length into the New Year.
- **Outlook:** Global prices are likely to remain low in the coming months, with potential support from a recovery in sulphur possible later in Q1. Limited planned smelter turnarounds may keep the market from recovering significantly as continued competition from Mexican exports may weigh on trade to Latin America.

KAZAKHSTAN

Kashagan operators facing \$740 million fine

Agip KCO and the North Caspian Operating Company (NCOC), the operators of the Kashagan field, have been issued with a \$740 million fine for the pipeline failure at the Kashagan oil and gas field, according to the Kazakhstan Ministry of Environment and Water Resources. The fine is for damages resulting from sour gas flaring at the processing facilities, following the pipeline leak on September 24th 2013, which saw highly sour gas released from a burst pipeline near the Bolashak onshore unit. Residual sour gas was flared at onshore and offshore Kashagan facilities during September and October 2013 as a result of the accident, totalling 2.8 million cubic metres according to the Environment Ministry, which is in receipt of a report from the Atyrau Department of Ecology into the incident.

Oil production at Kashagan began on September 11th, with commercial production due to begin on October 1st. On September 24th, however, a routine inspection of the gas pipeline running from Island D to Bolashak revealed a gas leak. The Kashagan field was shut down for repairs until October 6th, when oil production was resumed. The company said that the gas leak in the pipeline was caused by sulphide stress cracking.

SAUDI ARABIA

Sulphur loading facility contracts awarded

Saudi Arabia's Zamil Industrial Investment Company says that one of its subsidiaries has been awarded an 11.8 million riyal (\$3.14 million) engineering, procurement and construction (EPC) contract from South Korea's Posco Engineering & Construction Company to build a sulphur rail car loading facility being developed by Saudi Aramco at Jubail. The rail car loading facility is being built to facilitate the removal of molten sulphur from the Wasit and Berri gas plants in Khursaniyah and transport about 10,000 t/d of molten sulphur to the Ma'aden facilities at Wa'ad Al Shammal and Ras Al Khair. As per the deal, Zamil Air Conditioning and Refrigeration Services Company will provide engineering design services; materials procurement, supply, installation, testing and commissioning; and third-party consultancy services. It will also be responsible for the review and certification of the high-pressure water mist suppression system, automatic wet sprinkler system and the extinguishing control system for the railcar loading facility at the Wasit Gas Plant and Berri Gas Plant.

New control system for desulphurisation plant

The Saudi Aramco Mobil Refining Company (SAMREF) has selected Axens to evaluate, develop and implement an advanced process control (APC) system for their *Prime-G+* unit, which is used for the desulphurisation of fluid catalytic cracker (FCC) gasoline down to ultra-low sulphur levels. The objective of the APC system is to provide precise control of product sulphur content while minimising octane loss and reducing consumption of hydrogen and utilities. This project has been managed by Axens' APC experts in close collaboration with SAMREF engineers.

The SAMREF refinery is a 50-50 joint venture between Saudi Aramco and Exxon Mobil Corporation, formed in 1981 to develop oil refining facilities at Yanbu,. The refinery began operations in 1984 with a design capacity of 263,000 bbl/d of Arab Light Crude, but has since been expanded to process 402,000 bbl/d.

OMAN

Sulphur facilities part of new port development

Oman Oil Company, via its subsidiary Duqm Terminal, has invited expressions of interest (EoIs) from competent engineering firms for a contract to build storage and handling facilities for a major liquid storage terminal and dry bulk facilities planned at the seaport. The facilities form the second phase of works which are intended to underpin the development of a major refining and petrochemicals hub at the adjoining Special Economic Zone (SEZ) in Duqm on Oman's Wusta coast.

Interested contractors should submit letters of interest by January 22nd to seek prequalification to participate in a tender for the selection of an engineering, procurement and construction (EPC) contractor. The contract will entail the detailed design, procurement and construction of a package of works that includes, among other things, liquid storage tanks, pipelines and loading facilities, dry bulk handling facilities for pet-coke and sulphur storage, ship loaders and conveyors, buildings, roads infrastructure, and associated utilities.

Nine firms are already in contention for the first phase of the project, covering dredging and reclamation, as well as the detailed design and construction of quay walls and berths. Front-end engineering design (FEED) work on the overall project has been undertaken by WorleyParsons.

AUSTRIA

OPEC says there is no incentive to invest in SO_2 scrubbing

The Organisation of Petroleum Exporting Countries (OPEC), based in Vienna, has said that there is "little incentive" for ship owners to invest in sulphur dioxide scrubbing technology prior to 2020. That is the year that the International Maritime Organisation (IMO) aims to introduce a 0.5% global cap on sulphur cap in bunker fuels, although a review later this year could see this date pushed back to 2025. The IMO has said that shipowners can reduce emissions of SO_2 in other ways, for example by the installation of exhaust gas scrubbing systems, but OPEC's World Oil Outlook notes that there are questions remaining over scrubber waste stream disposal and thus the future acceptability of the technology, and the uncertainty over the date of implementation is also a deterrent to investing now. OPEC also notes that while the cost of fuel is likely to rise as refiners install desulphurisation technology to produce low sulphur marine fuels, these costs can generally be passed on to final customers, by raising delivered costs per container, per tonne of coal or per barrel of crude. Nevertheless, the organisation acknowledges that the same uncertainties are also a deterrent to refiners investing in such upgrades today.

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UNITED STATES

Axens to expand its sulphur abatement portfolio

Axens says that it has agreed to buy all assets and technology relating to sulphur removal products from Scutter Enterprises, LLC, for an undisclosed sum. Scutter, based in Chesterfield, Missouri, was created in 2009 and specialised in solid sulphur scavengers for gaseous and liquid streams. Axens says that the purchase will reinforce its adsorbent portfolio by the acquisition of the *HydroCat* range, which will now become part of Axens' *AxTrap*™ adsorbent product line. These adsorbents offer competitive purification solutions to process streams containing moderate amounts of sulphur in applications such as landfill gas, biogas, associated gas or CO_2 treatment, enabling the utilisation of these greenhouse gases with minimal environmental impact. Axens says that it will also retain all Scutter personnel in order to ensure continuity of service to existing and future customers.

"This acquisition gives us a great opportunity to complement Axens' portfolio of adsorbents", said Jean Sentenac, Chairman and CEO of Axens Group. "Thanks to Axens' global commercial network, we expect a strong development of sales of these new *AxTrap*™ products in North America and internationally."

Worker killed by sulphur pile collapse

A worker at the Port of Tampa was killed by a collapse of a sulphur pile while operating a front end loader, according to local authorities. Hillsborough County Sheriff's Office said that the Gulf Coast Bulk Equipment employee was moving sulphur to a trailer at the Port Redwing site when the 30-foot pile collapsed. The US Occupational Safety and Health Administration has begun an investigation into the incident.

CHINA

Production begins at Luojiazhai

On January 12th, the China National Petroleum Corporation (PetroChina) and US partner Chevron announced that they had begun commercial sour gas production at the onshore Luojiazhai A sour gas field on December 30th. Luojiazhai is part of the $6.4 billion Chuandongbei project, a sour gas development in China's southern sour gas-rich Sichuan basin. Hydrogen sulphide

Luojiazhai gas plant.

concentrations in the Chuandongbei fields average around 7-11%, making for higher operational risk and higher standards for technical processes. Chevron, with a 49% stake, is the project operator, and brings considerable operational experience with sour gas production. The project has faced delays from its original start-up date of 2010. Initial production is targeted at 250 million scf/d (approximately 3 bcm per year) in the first phase, rising to 750 million scf/d in 2018. A 30-year production sharing deal between the two companies was signed in 2008.

MEXICO

Fluor wins Hidalgo refinery upgrade

Fluor Corporation says that it has signed a contract with Pemex to supply detail engineering, procurement and construction (EPC) services for the utilities and offsites that are part of the Tula Refinery upgrade at Hidalgo, Mexico. The total contract value is $1.1 billion.

"This project is a major step to increase Pemex's competitiveness," said Juan Carlos Santos Fernandez, director general of ICA Fluor. "We are proud to be in the position to support them in the development of the strategic projects required by the country, providing Mexican engineering and construction resources."

Once the upgrade project is completed, the refinery's processing capacity will increase from 315,000 bbl/d to 340,000 bbl/d. The project's mechanical completion is scheduled for the second quarter of 2018.

Government plans $23 billion refinery upgrades

Mexican president Enrique Peña Nieto has announced investments totalling $23 billion over the next three years to upgrade state-owned oil giant Pemex's six refineries, making petroleum production "more efficient" in a "changing environment." The projects include reduction of the sulphur content of fuels as well as emission cuts of greenhouse gases and pollutants by about 90%, as well as use of petroleum residues, low-sulphur diesel and cogeneration. The ultra low-sulphur gasoline project, which will cost $3.1 billion and be completed in 1Q 2016, will allow Mexico to produce 212,500 bbl/d of the fuel, while the $3.9 billion low-sulphur diesel project will help cut imports of the fuel.

CANADA

RioTinto allowed to increase SO_2 emissions

The British Columbian Environmental Appeal Board has ruled in favour of Rio Tinto Alcan's permit to increase sulphur dioxide emissions (SO_2) from its 60-year old Alcan aluminium smelter in Kitimat. The permit, granted in 2013, allowed Rio Tinto to increase SO_2 emissiosn as part of the company's modernisation of the aging Kitimat smelter. The project, which nearly doubled the plant's production, will decrease greenhouse gas emissions but raises sulphur dioxide emissions by 56%. The BC Ministry of the Environment granted Rio Tinto permission to modernise the smelter but did not require the company to install scrubbers. Locals environmentalists challenged the permit but the appeal board ruled in favour of upholding the initial ruling.

AZERBAIJAN

SOCAR awards refinery contract

The State Oil Company of Azerbaijan Republic (SOCAR) has selected Axens to license clean fuel technologies for SOCAR's Heydar Aliyev Oil Refinery at the port of Baku as part of a major modernisation project for the refinery. The modernisation programme will see the refinery increase its annual processing capacity from 6.0 million t/a to 7.5 million t/a, as well as bringing the refinery output to Euro-V standard. As part of the project, Axens is providing the following technologies:

A *Prime-G+*™ gasoline desulphurisation unit with a design capacity of 1.2 million t/a.

A *Prime-D*™ diesel hydrotreater unit with a design capacity of 3.0 million t/a.

Axens says that SOCAR's interest in them as a partner stems from Axens' involvement in the STAR refinery project in Turkey, supplying naphtha, kerosene and diesel hydrotreating processes. ■

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Sulphuric Acid News

FINLAND

New acid plant for Harjavalta smelter

Boliden is planning to build another sulphuric acid plant at its Harjavalta smelter in Finland. The company says that this will continue the development of its copper-nickel business and will lead to improved environmental performance and operational efficiency. Boliden Harjavalta currently operates two acid plants which produce sulphuric acid and liquid sulphur dioxide from smelter off-gases formed in the copper and nickel smelting processes. The new, more efficient acid plant, will be part of an investment programme running to 2019, with a total investment cost of euro 90 million. Once operational, SO_2 emissions will be reduced by 20-25% and cooling water requirements by 40%, as heat will be recovered, resulting in higher energy efficiency. In addition the removal of minor process bottlenecks on the copper side will make future expansion projects possible on both the copper and nickel lines, according to Boliden.

"The performance of Boliden Harjavalta has developed positively over several years. This investment improves our technical infrastructure which is fundamental for our long term competitive position. Continuity of the site together with the improved environmental performance is important for our local community too," said Timo Rautalahti, General Manager Boliden Harjavalta. ■

AUSTRALIA

Freight train derailment causes acid spill

A freight train carrying sulphuric acid derailed in December in a remote area of Queensland, northern Australia. According to Queensland police, 819,000 litres of acid was on board the 26-car train at the time. A 2 km exclusion zone was established around the crash site, necessitating the closure of a nearby highway. One of the carriages was found to have ruptured, and an estimated 31,500 litres of acid leaked out, although according to police, testing by the Queensland Department of Environment and Heritage Protection in the area of the incident indicates that the nearby Horse Creek waterway was not adversely affected. The train was carrying acid to the Mount Isa phosphate processing site. Three train crew were injured in the incident, but none seriously.

New mine to start up this year

Australian mining company Venus says that it expects to begin production at its new phosphate mine in north-west Queensland by the middle of 2016. The news follows successful test pit mining at Korella, 170 kilometres from Mount Isa. The company said in a statement that it expects production to begin in 1H 2016, with first shipments of rock in May or June. The mine will pave the way for future exploration in the area, and Venus says that once production is up and running and cash flowing, it has an "extensive" exploration programme planned for 2017. Initial production will be 600,000 t/a for eight years. Venus says that it is also developing rail and port infrastructure programmes.

Iffco payment upheld

The Supreme Court of Victoria State has upheld a ruling by a Singaporean arbitration panel that Legend International Holdings must pay Indian fertilizer company Indian Farmers Fertilizer Cooperative (Iffco) A$55 million over a $1 billion phosphate deal that went sour. Legend owner Joe Gutnick was accused by Iffco of selling them a large stake in Legend in 2008 via "fraudulent misrepresentation". The deal was part of an offtake agreement that was to see Iffco take up to 5.0 million t/a of phosphate from Legend, worth about US1 billion at the time. Iffco bought 34 million shares in Legend, ending up owning 15% of the company. However, Legend did not produce the phosphate due to a slump in price, and the value of the shares fell at the same time.

Speaking to the Australian press, Mr Gutnick said that he would appeal the ruling, and argued that Iffco should have performed due diligence on the deal. However, the contract with Iffco had a clause which obliges Legend to accept the result of arbitration, and under an international agreement that forms part of Australian law, it is not possible to challenge the merits of an arbitration decision in court.

CANADA

Ariane gets go-ahead for Lac a Paul

The Canadian province of Quebec has approved plans for junior mining company Arianne Phosphates to develop the C$1.2 billion Lac à Paul phosphate rock project. The open-pit mine is expected to create 475 construction jobs and 375 permanent mining and processing positions, with commercial production expected to begin in 2019. Lac à Paul will produce approximately 55,000 t/d of ore, with an annual production of 3 million t/a of apatite concentrate. Measured and indicated mineral reserves are 590 million tonnes.

Jean-Sebastien David, Arianne's COO, said in a press statement: "There could not have been a better way to end the year for Arianne and the region as a whole. The Ministerial Decree represents the most significant milestone to date for the project and with it, The board and the Arianne team want to thank the Government of Quebec for the confidence they have shown in this project through the issuance of the Decree and, of course, greatly appreciate the support we have received from the municipalities and organizations that have been behind this project." The company says it will now focus on securing financing for the construction phase.

NAMIBIA

Weatherly trades acid price cut for Tsumeb option

Namibian copper producer Weatherly International says that it has sold its option to purchase the Tsumeb tailings facility from Dundee Precious Metals for $4 million. The consideration will be paid via Weatherly receiving a discount of $40/t on acid that it purchases from Dundee for use at its Tschudi heap leach operations. JORC resources at the Tsumeb tailings dam were estimated in 2011 at 12 million tonnes at 0.48% copper, 0.77% lead, 0.63% zinc and 12.74 g/t silver in 2011. Industry analysts RFC Ambiran say that, given expectations of acid consumption of 20 kg/t of ore treated during 2016 and 10 kg/t thereafter, the sale will have a payback period of four years, with an estimated reduction in copper production costs over that period of $59/t.

UNITED STATES

New sulphuric acid alkylation process

Refining Hydrocarbon Technologies (RHT) Ltd, based in Kay, Texas, says that it has completed pilot testing and is now ready to commercialise its new sulphuric acid alkylation process. Alkylate, the main component in high-octane gasoline, is produced by catalytic reaction of C3–C5 olefins with isobutane in the presence of a strong acid catalyst. Although there has been progress in the use of solid acid catalysts, sulphuric acid alkylation has become increasingly popular in recent years due to safety and environmental concerns with hydrofluoric acid alkylation, according to RHT.

The RHT process is based on classical sulphuric acid alkylation chemistry that has been used since the 1940s, but uses a unique mixing device that requires less energy and maintenance than alternative processes, and works at lower temperatures at essentially isothermal conditions, according to Amarjit Bakshi, president and CEO of RHT. Low-temperature operation favours the formation of the desired high-octane product (trimethylpentanes and dimethyl hexane), while minimising side reactions, such as polymerisation, disproportionation, cracking and the formation of unstable esters of H_2SO_4.

Other features of the RHT technology are a reduction in acid consumption to about 50% of the conventional processes and an advanced coalescer design and operating conditions for enhanced separation of the acid and hydrocarbons. As a result, a neutralisation stage – required in conventional processes – is not needed, which results in a 'dry' process, with reduced corrosion issues.

SWITZERLAND

Phosphorus recycling becomes obligatory

Switzerland has become the first country in the world to make phosphorus recovery and recycling from sewage sludge and slaughterhouse waste obligatory. The new regulation came into force on January 1st 2016, with a transition period of 10 years. Switzerland banned the direct use of sewage sludge on land in 2006, so the regulation will lead to technical recovery and recycling in the form of inorganic products. Swiss sludge and slaughterhouse waste together already represent an annual flow of 9,100 tonnes P_2O_5, as compared to technical recycling from wastewater streams in Europe today, which total around 1,000 tonnes P_2O_5, in the form of struvite. Details such as the required efficiency of the recovery process and plant availability of fertilizer is to be defined in collaboration with Swiss stakeholders, according to the European Sustainable Phosphate Platform.

TUNISIA

Plans for new acid, TSP plant

Groupe Chimique Tunisien (GCT) has signed an agreement with several Chinese companies in order to create a new triple superphosphate (TSP) plant. The CEO of GCT subsidiary Gafsa Phosphate Company (CPG), Romdhane Souid, said that the production capacity of the new Mdhilla 2 unit will be 400,000t/a of TSP. The plant is due to be on-stream in 2018, with a total investment of 600 million Tunisian dinars ($310 million), and will include sulphuric and phosphoric acid capacity.

CPG had a far more successful second half of 2015 as compared to the first half, with production rising from 935,000 tonnes of phosphate in 1H 2015 to 2.3 million t/a in 2H 2015. Tunisia is looking to bring phosphate rock production to 6.5 million t/a in 2016, according to Souid, now that there has been a resolution to the strikes and protests that have plagued Tunisian phosphate production over the past few years.

SAUDI ARABIA

Ma'aden to borrow $1 billion

The Saudi Arabian Mining Company (Ma'aden)'s subsidairy Waad Al Shamal Phosphate Company has secured a 4 billion riyal ($1.07 billion) loan from the state-owned Saudi Industrial Development Fund (SIDF) as part of its plans to build new phosphate capacity in the country. A SR900 million facility will fund building an ammonia plant, while a separate loan for the same amount will finance construction of a diammonium phosphate plant. Both loans will be repaid in 14 semi-annual installments over seven years, with the two plants to be built in Ras Al-Khair. Two further loans – of SR1 billion and SR1.2 billion respectively – will fund building plants to manufacture sulphuric acid, phosphoric acid and phosphate concentrate in Waad Al Shamal. These loans are for eight years and will be repaid in 16 semi-annual installments.

BRAZIL

South32 may bid for Anglo's phosphate business

South32, the aluminium, coal and manganese producer spun out of BHP Billiton last year, is reportedly considering bidding for Anglo-American's $1 billion niobium and phosphate business in Brazil. The company is said to have sent out requests to investment banks as it seeks to hire an adviser to assist in the bidding process. First-round bids are due by the middle of next month, and Anglo is seeking to complete the sale in one transaction, rather than split the niobium and phosphate assets. Large North American fertiliser companies may participate in the auction, according to Bloomberg. Anglo confirmed last month that it would work to sell the business this year, as part of a plan to raise $4 billion to cope with the collapse in commodity prices. It has already raised $2 billion from sales of two of its Chilean copper mines, as well as South African platinum production and its tarmac business.

South32, based in Perth, Australia, was created last year as BHP narrowed its focus to copper, coal, iron ore and oil.

GUINEA BISSAU

GB Minerals completes test work for phosphate project

Phosphate junior GB Minerals says that it has successfully completed its phosphoric acid and diammonium phosphate (DAP) test work based on the output of its beneficiation pilot plant at its Farim phosphate project. The company says that CaO/P_2O_5 ratios contained in the Farim phosphate are amongst the world's lowest at 1.41, resulting in low sulphuric acid consumption and less phosphogypsum production. Results indicate that a 34.0% P_2O_5 product could be achieved by washing, scrubbing and particle sizing only, and that by adding a silica flotation step, the grade could be increased to 35.9% P_2O_5.

"The successful phosphoric acid and DAP tests clearly demonstrate the viability of the Farim project and further support our belief that the Farim phosphate deposit is one of the highest quality in the world. The benefits downstream to potential customers are even more apparent with these results. The company is in active discussions with multiple parties for key offtake agreements and we hope to start updating shareholders on these discussions," said Luis da Silva, president and CEO. ■

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People

Fluor Corporation has agreed to acquire 100% of Stork Holding BV, based in the Netherlands, for €695 million ($755 million). Stork is a global provider of maintenance, modification and asset integrity services associated with large existing industrial facilities in the oil and gas, chemicals, petrochemicals, industrial and power markets.

"The acquisition of Stork is consistent with Fluor's goal to further enhance our integrated solutions capabilities in thoughtful, strategic ways that will increase the value we deliver to our clients and shareholders," said Fluor's Chairman and CEO David Seaton. "Stork's business is largely driven by ongoing operating budgets and is therefore less impacted by volatile commodity prices. In addition, Stork's continuous site presence will help us improve our ability to meet our customers' needs throughout the full lifecycle of an operating plant, and provide Fluor with an ongoing earnings stream and robust growth opportunities.".

Following the acquisition, Fluor will begin combining its Operations & Maintenance organisation with Stork. Current Stork CEO, **Arnold Steenbakker**, will lead the combined group and report directly to Fluor's CEO, **David Seaton**. The management team will be formed by Stork's existing management combined with the managers of Fluor's Operations & Maintenance business. The combined group, branded Stork and headquartered in the Netherlands, will have an annual turnover of approximately €2.1 billion ($2.3 billion) and a total of approximately 19,000 employees.

Potash Corporation of Saskatchewan (PotashCorp) has announced that **David Delaney**, Executive Vice President and Chief Operating Officer, will retire effective from January 31st, 2016. Delaney has held his present position since 2010, and led the company through the largest expansion programme in its history.

"David's contribution to the company's success spanned almost two decades," said **Jochen Tilk**, president and CEO. "Having spent the majority of his career at PotashCorp leading our Sales team – and more recently our Operations group – David built many strong relationships with his colleagues and others within the industry, and will be missed."

With Delaney's departure, the presidents of the company's business units – Mark Fracchia, Raef Sully and Paul Dekok, of the Potash, Nitrogen and Phosphate units respectively, will now report directly to Tilk.

DuSolo Fertilizers has appointed **Giles Baynham** as its new chief executive officer. **Darren Bowden** has resigned as interim CEO, but will remain with the company as a director. Baynham is a mining engineer and financier with 19 years experience in the natural resources industry. He is experienced in the evaluation and financing of mining projects, from early stage exploration to production. He began his career as a mining engineer with Rio Tinto, before working at various financial entities including Mizuho Corporate Bank, NM Rothschild & Sons, and Endeavour Financial, and was a co-founder, director and president of CB Gold Inc.

DuSolo Fertilizers chairman Eran Friedlander said; "Mr. Baynham's experience in financing mining projects make him a great addition to DuSolo's management team, and he will be focused on executing the Company's development plan. We would also like to take this opportunity to thank Darren for his significant contribution over the last 6 months and are pleased that his experience and expertise will still be available to the company in his role as a director."

DuSolo is processes high-grade phosphate into direct application fertilizer in Brazil. It says it intends to capture 30% of the market for phosphate in the north-eastern region of the Cerrado in the coming three years. ■

Calendar 2016

JANUARY

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ASRL Chalk Talks and Poster Session, CALGARY, Canada.
Contact: ASRL, University of Calgary, Alberta T2L 2K8 Canada.
Tel: +1 403 220 5346
Fax: +1 403 284 2054
Email: asrinfo@ucalgary.ca

FEBRUARY

21-24

66th Laurance Reid Annual Gas Conditioning Conference, NORMAN, Oklahoma, USA.
Contact: Betty Kettman, University of Oklahoma.
Tel: +1 403 325 3136
Email: bettyk@ou.edu

MARCH

13-15

Phosphates 2016, PARIS, France.
Contact: CRU Events, Chancery House, 53-64 Chancery Lane, London WC2A 1QS, UK.
Tel: +44 20 7903 2167
Email: conferences@crugroup.com

20-22

AFPM Annual Meeting, DALLAS, Texas, USA.
Contact: Yvette Brooks
Email: ybrooks@afpm.org
Web: www.afpm.org

20-24

SOGAT 2015, ABU DHABI, UAE.
Contact: Dr Nick Coles, Dome Exhibitions.
Tel: +971 2 674 4040
Email: nick@domeexhibitions.com

APRIL

11-13

TSI World Sulphur Symposium, VANCOUVER, Canada.
Tel: +1 202 331 9660
Email: sulphur@sulphurinstitute.org
Web: www.tsi.org

MAY

22-26

2nd Annual Brimstone Sulphur Symposium, ABU DHABI, UAE.
Contact: Brimstone STS Ltd
Tel: +1 909 597 3249
Fax: +1 909 597 4839
Email: mike.anderson@brimstone-sts.com

30 – 1 June

84th IFA Annual Conference 2016, MOSCOW, Russia.
Contact: IFA Conference Service
Tel: +33 1 53 93 05 25
Email: conference@fertilizer.org
Web: www.fertilizer.org

JUNE

10-11

40th AIChE Annual Clearwater Conference 2016, CLEARWATER, Florida, USA.
Email: chair@aiche-cf.org
Web: www.aiche-cf.org

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Changing sulphur market trends

Janos Gal, principal sulphur analyst with Fertecon, provides an overview of the changing global sulphur market, in the wake of new supply sources.

Canada's top spot on the world sulphur stage will soon be overtaken by the Middle East, as sour gas fields across the region will add several million tonnes of sulphur to the world's annual supply. It is estimated that the current global output of 53 million tonnes per year could increase to more than 70 million t/a by 2018, and most of the additional supply will emerge from the Middle East and Central Asia.

The dominance of Canada as the world's primary supply source largely stemmed from its role as the main supplier to the US and also its importance as a solid sulphur supplier from Vancouver to various markets, including China and Australia. Most of the sulphur in the country is derived from oil and gas production (as in almost every other country in the world), but unfortunately for the sulphur producers, they are located far from both Vancouver and the largest consumers in the US.

Whereas most of the tonnes shipped from Vancouver are transported in solid form, buyers in the US consume liquid sulphur. From 2004 to 2006 Canadian sulphur exports surpassed 8 million t/a, but this has steadily declined, falling to just over 4.7 million tonnes in 2015, as shown in Figure 1.

In the future, more Canadian sulphur might be poured into block if Middle Eastern prices reduce substantially as more supply comes into play. During the early 2000s, the "psychological" barrier for Canadian exporters was about $50-60 fob Vancouver and if prices fell below that, exports were reduced until prices went up again. However, since then mainland freight has gone up – some sources suggest $80-90/t – so the minimum export cost is likely to have increased accordingly.

The challenge that Canadian exporters face when it comes to competing against the Middle East is that they have to get the sulphur to Vancouver (1,000 miles from the production sites) while at the same time remaining competitive against ex-Middle East values. Therefore, if the Middle East cuts prices below $80-90 fob, we can reasonably expect the Canadians to reduce exports, although the Middle Eastern sellers might prefer to keep prices as high as possible knowing they could slash them at any time if necessary.

Exports to US

At present Canada has more than 11.5 million tonnes sulphur in block with the expectation that this could increase further in the future, and not just due to lower price levels. Mosaic, one of the largest consumers of Canadian liquid sulphur, is building its own sulphur remelter with an annual capacity of 1 million tonnes. It will import solid sulphur for the plant from various sources such as Kazakhstan and the Middle East. The plant was expected to start up in December but Mosaic decided to delay bringing the plant on-stream until late January 2016 because of extremely high liquid sulphur availability and it needs to be able to fulfil their molten contract commitments.

Assuming that Mosaic operates the plant at full capacity, it can potentially displace 1 million tonnes/year of liquid sulphur that it is presently buying from the US, Mexico and Canada (see Figure 2). What is not yet clear is at what rate Mosaic will operate its plant and from where it will reduce its purchased requirements. As such, it remains to be seen whether it will buy less liquid from Canada, Mexico or the US domestic market. In terms of freight costs, the most expensive freight is from Canada (more than 3,000 miles and around $100/tonne from Northern Alberta).

However, according to some industry sources, the Mosaic remelter will not necessarily cause in itself more Canadian tonnes to be blocked. That is because in a balanced market the Canadians would export offshore whatever they don't ship to Florida. So it's the global balance, which is not impacted by whether Mosaic buys liquid from Canada or imports solid, which determines blocking in Canada. Canadian exporters will also have to be 'globally competitive' if they want to remain in the sulphur business – even if it means negative netbacks from time to time.

The remelter will also result in the emergence of new trade routes that never before existed, such as sulphur shipments from the UAE and Kazakhstan to the US Gulf. It could also force US Gulf producers to make more solid sulphur and export it to Brazil or other markets such as Morocco, Namibia or elsewhere, although options are somewhat limited given the distances involved to major markets in China and India. What might happen is that more US Gulf sulphur will make its way to Brazil, prompting Brazil to buy less from Kazakhstan. The Kazakh sulphur which is not sold to Brazil could then end up in the hands of Mosaic. One might argue that this makes little sense as these shipments will very likely pass each other on their respective voyages, but this scenario is looking increasingly likely.

Additionally, with high logistics costs from Canada to Tampa and fewer molten sulphur rail cars, it could become uneconomical at some point to import sulphur from Canada. In contrast, bulk sea freight rates are falling as a result of a supply glut and a slowdown in commodity trading activity, so it is perfectly possible that shipping sulphur from the UAE could actually be cheaper than bringing liquid sulphur in from Canada. What is also important to remember is that Mosaic's sulphur consumption is not changing, but what will change is the form in which it consumes the sulphur.

In terms of negotiating power, having an in-house remelter could give Mosaic the flexibility to reduce its reliance on domestic suppliers and to use the plant as a bargaining chip during contract negotiations. According to press reports, the construction of the plant cost more than $20 million, so if Mosaic achieves a $20/tonne reduction in just one quarter due to the cost saving from the remelter, it will have already paid for itself based on a quarterly consumption of 1.25 million tonnes sulphur. Mosaic has already imported a total of 59,000 tonnes Kazakh sulphur and one UAE cargo in 2015 for commissioning runs and for its other 50/50 joint venture remelter in Galveston.

Mosaic says that it intends to buy solid sulphur to feed the melter from various suppliers and not from any one specific supply source or region which it expects will help it to provide flexibility in pricing. While significant sulphur production expansions are taking place in the Middle East, there are also expansions taking place in Kazakhstan and in several other locations around the world. Therefore, the buyer expects sulphur availability to improve, which in the long-term it hopes will keep its price at affordable levels.

Brazil

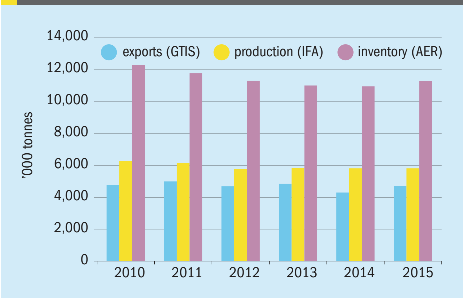
Moving further south, Brazil has already experienced some changes in its buying patterns for sulphur. In 2015 Vale imported a substantial volume from the UAE due to increasing availability from Adnoc. Vale already imports from Kuwait and Saudi Arabia, but they are not regular shipments, whereas quantities from the UAE were substantial at 160,245 tonnes in 2015 with the potential to increase further in 2016.

Another source of additional supply for Brazil has been and will continue to be the US Gulf. Imports into Brazil between January and November 2015 stood at 689,767 tonnes, and if US producers need to increase exports further, they are best placed to compete on pricing being the closest to Brazil. The proximity of the US Gulf also means lead times are shorter and Brazilian buyers already tend to rely on US material for spot purchases.

The third main supply source for Brazil in 2015 was the FSU, with Russia at just under 418,000 tonnes followed by Kazakhstan at 417,196 t, more or less the same volumes as in the previous two years.

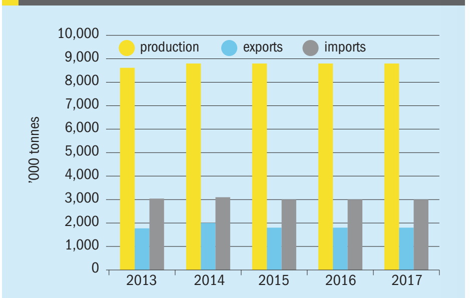
How much of an impact the additional UAE sulphur and Mosaic's remelter will have on Brazil remains to be seen, but what is certain is that the country's consumption will likely remain stable with little room for short-term growth, so if it decides to buy more from one place, it necessarily follows that its requirement from one or other of its traditional sources will be reduced accordingly.

Fig 1: **Canadian sulphur production**



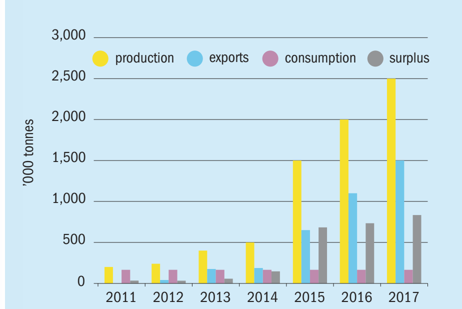
Source: Fertecon

Fig 2: **US sulphur production**



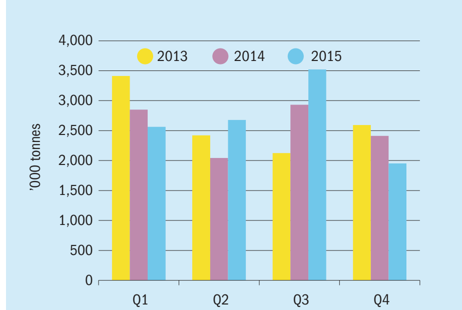
Source: Fertecon

Fig 3: **Turkmenistan sulphur exports**



Source: Fertecon

Fig 4: **Chinese sulphur demand by quarter**



Source: Fertecon

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Kazakhstan

Kazakhstan's sulphur availability at present is about 2.5 million tonnes/year, and this could increase to about 3.5 million tonnes/year when the severely delayed Kashagan gas field starts up in 2017 (see Figure 3). The Tengizchevroil (TCO), block has now been broken up and shipped out of Kazakhstan and thus exports started to decline from August 2015. Fertecon therefore expects that between now and 2017 exports will remain steady at around 2.5 million t/a. The main destinations have been Brazil, China, Morocco and more recently the US. In a similar way to Brazil, if Kazakhstan's exports increase to one country this year it will need to export less to another given the limited supply forecast through 2016. Being landlocked, most of the sulphur is railed to Ust Luga in the Russian Baltic for onward shipment to Brazil, US and Morocco. Most of the deliveries to China are transported by rail through Alashankou.

Turkmenistan could also become a major source of supply in the future, having started up a substantial sour gas field near Galkynysh. Sulphur output in the country is estimated to increase from minimal amounts five years ago to 2.5-3.2 million tonnes by end 2016/2017. Some sales are concluded under contract while large volumes are also auctioned off at the Turkmen Stock Exchange. The last known sales by auction were at $23-25 ex-works in 2015.

An increasing number of tonnes from Turkmenistan have been finding their way to China as well as other destinations and it has been suggested that exports could increase in 2016 if traders find alternative trade routes, for example via Ust Luga in Russia. Some have dismissed this, arguing that freight from Ust Luga to China would be prohibitively high. Nevertheless there has been speculation that at least one trader has received a substantial discount on rail freight from Turkmenistan to Ust Luga, which might be advantageous and which could make it work for delivery to China.

Exporters from Turkmenistan have so far been using two ports, namely Poti in Georgia and Bandar Abbas in Iran but, as already mentioned, Ust Luga in Russia is also being considered. At present it is understood that excess sulphur that is not exported or consumed in the domestic market is stored in the open at nearby sites. Current freight cost estimates vary widely, generally ranging between $100-150/tonne to China and slightly less to Morocco. So far Morocco has bought close to 100,000 tonnes but logistics remain complicated and quantities may therefore be reduced over the coming year.

China

China's role as an importer of Turkmen sulphur could become more dominant, especially since PetroChina has direct access to this source of supply. Current estimates suggest that about 500,000 tonnes sulphur was shipped to China in 2015, which could double next year with the development of a new route through Ust Luga.

If China buys more from Turkmenistan and its domestic production also increases, it will more than likely reduce its imports from its traditional suppliers in the future. China is the world's largest consumer and importer of elemental sulphur. It imported just over 11 million tonnes of sulphur in 2015, equating to about one-third of global sulphur trade 9 see Figure 4).

The Chinese fertilizer sector is the main consumer for the production of sulphuric and phosphoric acid, consuming about 16 million tonnes of sulphur annually. It is estimated that the phosphoric acid industry accounts for two-thirds of total sulphuric acid use in China. The increase in domestic sulphur availability could potentially result in a drop in imports and could ease Chinese end-users' reliance on Middle Eastern sulphur supply. Domestic sulphur supply is forecast to increase to an estimated 7.7 million t/a by 2017 from the current level of 5 million t/a. In 2015, the country's average monthly sulphur production rate from various refineries was 420,000 tonnes.

Assuming that China buys an additional 1 million t/a from Turkmenistan and its annual domestic production rises by 2 million tonnes by 2017, it will displace 3 million tonnes imported sulphur from supply sources such as Canada and the Middle East – unless consumption goes up at the same rate for fertilizer production but this is not expected. Imports from India also increased in 2015 and this is unlikely to change as some Chinese traders receive a subsidy if importing from Iran and India. As such, to maintain or grow their market share, Middle Eastern suppliers may cut prices to compete against suppliers such as Turkmenistan and Canada; the latter in turn may decide to pour more sulphur into block.

Middle East

Aside from all the changes in North America and Asia, the real game changer will be the Middle East, where supply will increase by several million tonnes during the next few years. Abu Dhabi could become the largest sulphur supplier in the world as a result of huge quantities produced from various sour gas fields.

Adnoc's annual sulphur production is expected to gradually increase to 5.5-6.5 million tonnes by the end of 2016 from 2.5 million tonnes per year in 2013 with additional capacity coming online at the Shah gas field and also from oil refining. In the very long term, the Bab gas field could also be developed into a major source of sulphur, increasing the country's annual output further to 8 million tonnes.

The operations at Shah include an 11,000 tonnes per day sulphur handling facility, a new railway line, new port facilities and an additional 300,000 tonne storage unit, which will bring Adnoc's storage capabilities to nearly 600,000 tonnes. The plant will process 9,200 t/d of sulphur.

A large part of this supply has been committed to OCP's phosphate units in Morocco, consuming about 2 million tonnes per year UAE sulphur from 2015/2016. The Shah unit has already reached full production capacity. Adnoc has also plans to supply Mosaic's new sulphur remelter while exports are expected to increase to Brazil, India, China and other parts of Southeast Asia as well as South Africa.

The biggest advantage the UAE has is its modern rail and port infrastructure, enabling it to move sulphur fast. The first phase of Etihad Rail, a rail link across the UAE, was completed in 2014, connecting Shah and Habshan to the port of Ruwais. The 266 km stretch is used for moving granular sulphur to the port from production plants. It can carry up to 22,000 tonnes of sulphur each day on 110 railcars, equivalent to 360 truck-loads.

Another Middle East major is Saudi Arabia. Its total sulphur capacity in 2014 was around four million t, which will gradually increase to about 5.6 m tonnes/year by 2017. The main sulphur handling and export facilities are located in the Red Sea and at Jubail. On the Red Sea coast there are refineries in Yanbu and Rabigh, which also serve as export ports.

The increases will come from oil refining and additional capacity from the offshore Wasit gas field as well as sour associated natural gas processing from Saudi Aramco's Khursaniyah plant and the commissioning of the new Karan process-

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ing plant with a 300,000 tonnes/year sulphur recovery unit.

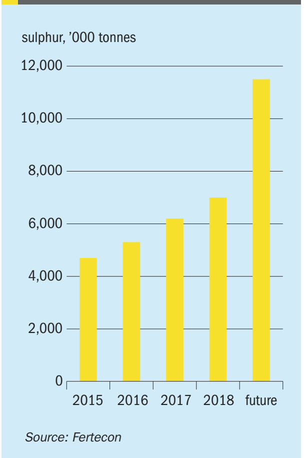
There are also major developments in the oil refining sector. Yanbu Aramco Sinopec Refining Company (Yasref), a joint venture between Saudi Aramco and Sinopec, started up production at the new 400,000 barrels/day refinery in Yanbu in 2015. The refinery's sulphur capacity is estimated at 35-50,000 tonnes per month. Saudi Aramco's other brand new plant, the Jazan refinery in the Kingdom's southwest is expected to be operational in 2016 with a nameplate capacity of 400,000 barrels per day.

Demand

On the demand side, one of the two main developments at present that could soak up large quantities of sulphur is OCP's massive expansion programme at Jorf Lasfar and Safi in Morocco. OCP's initial plant is to construct a total of 10 new integrated phosphate units at Jorf Lasfar, with financing for four of those in place and the first two already commissioned. The next two will be brought onstream over the next two years. Once four are built, OCP's annual sulphur requirement will increase by 2 million tonnes by 2017-2018, as each burner has an annual capacity for 500,000 tonnes sulphur (Figure 5).

OCP is expected to start-up JPH-2 during Q2 2016. As with JPH-1 in Q2 2015, the 1.45 million tonne/year sulphuric acid unit will be brought on-stream first, to be followed thereafter by the phosphoric acid unit.

Fig 5: **OCP sulphur demand**



Source: Fertecon

Another important consumer will be Saudi Arabia's phosphates industry. There are currently two plants operating in the country, one of which is the Ibn al-Baytar DAP plant in Al Jubail which operates on purchased phosphoric acid.

The other major prospective consumer is The Ma'aden Phosphate Company near Ras al Kair in Saudi Arabia with an on-site sulphur burner to produce sulphuric acid. The sulphur burner consumes 1.5 million tonnes per year of sulphur. A third plant, the Wa'ad al Shamal, is under construction. It will have capacity to produce 1.5 million tonnes P_2O_5 per year, with an annual requirement for a further 1.5 million tonnes sulphur. The plant is expected to start up in late 2016.

The Saudi national rail operator has already bought 1,200 tank wagons to serve Ma'aden's Wa'ad al Shamal Industrial City. The wagons will be used to carry molten sulphur and phosphoric acid on the North–South Railway. These plants' sulphur requirements will be met by domestic liquid sulphur supply, thus reducing Saudi Arabia's export capabilities.

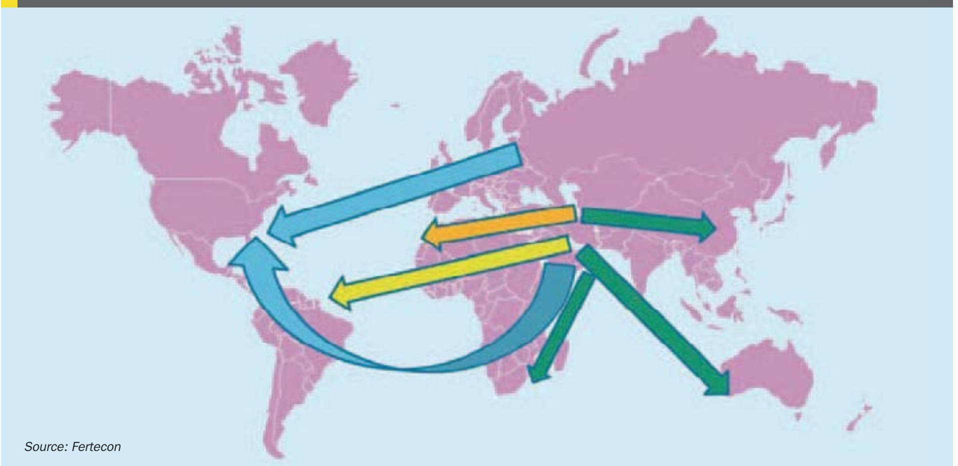
Another potential outlet for some of the extra sulphur from the Middle East could be Tunisia, but that entirely depends on the political situation in the country. Due to strikes and various other geopolitical factors, imports in 2015 dropped to 519,550 t, down from close to 1 million tonnes in 2014. Prior to the start of the social unrest in Tunisia in 2011, when the phosacid units were running close to capacity, Tunisia's annual sulphur requirement was nearer to 1.8-2.0 million tonnes in a normal, pre-uprising year.

Jordan has become an important outlet, consuming nearly 1 million tonnes/year sulphur with the addition of new phosphoric acid capacity. JIFCO's new phosphoric acid plant has a daily production capacity for about 1,500 tonnes P_2O_5 phosphoric acid, 4,500 tonnes sulphuric acid equivalent to about 1,500 t/d sulphur consumption, or about 45,000 tonnes per month. The first shipment of sulphur to JIFCO, the joint venture between IFFCO/India and JPMC, loaded in Ruwais, Abu Dhabi mid-June 2014, comprising a 50,000 tonnes shipment from Adnoc.

JPMC's main plant in Aqaba has been producing at around 60% capacity through 2015 due to production limitations. This should increase in 2016 following a debottlenecking project, which theoretically should increase the buyer's sulphur requirements in the long run. A third plant in the country is the IJC plant, majority owned by JPMC with a 224,000 tonnes P_2O_5 phosphoric acid capacity.

Other new minor outlets from the metals and fertilizer industries that are expected to start-up around the world between 2016-2018 include Indonesia, Vietnam, Kazakhstan and Cuba.

Fig 6: **Changes to global sulphur trade patterns**



Source: Fertecon

Metal leaching

The metals industry is one of the fastest growing demand segments for sulphur with various advancements in metal processing, enabling companies to process previously high cost and high risk ores. The spread of the high pressure acid leach (HPAL) and heap leach (HL) processes consume vast quantities of sulphuric acid, most of which is produced on site using sulphur burners. Total sulphur consumption globally for this sector is estimated between 4.5-6.0 million tonnes/year.

The main companies that use sulphuric acid for leaching are Sherritt (Cuba, Madagascar), Ramu (Papua New Guinea), Vale (Indonesia, New Caledonia), Glencore and FQM in Australia, Taganito and Coral Bay in the Philippines as well as Skorpion Zinc in Namibia. Another zinc leaching plant is in Moorseboro, US, with a similar capacity to Skorpion Zinc. However, demand from the copper belt in Africa, especially Zambia, is decreasing because of the start-up of new sulphuric acid plants attached to copper smelters. Noracid has a major sulphur burner in Chile that also serves the domestic metals industry.

Conclusions

As we have seen, it appears that the next two-three years could be very eventful as supply will inevitably outstrip demand and many have begun to ask how the imminent sulphur Tsunami will change the global landscape. With more stringent environmental regulations as well as fewer options to store sulphur, oil and gas producers will be hard pressed to ensure that the smooth running of operations will not be disrupted by a pile of sulphur which they cannot shift from their backyard. New gas and oil developments will increase sulphur production to an estimated 71 million tonnes by 2018 but at the same time major downstream developments are lagging behind and so it seems that a major surplus of sulphur is imminent. As with anything, the easiest way to compete will be to reduce prices and at present Middle Eastern suppliers are best placed to shift large volumes at short notice as they have the best and latest in logistics technology. How this will play out remains to be seen, but there are certainly a few exciting years ahead. ■

Janos Gal is Fertecon's principal sulphur analyst working on its weekly sulphur report, as well as a new monthly report published by Fertecon's parent company, Informa, to be launched in February.

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Controlling refinery emissions of SO_2

Environmental legislation is continually tightening, and nowhere more so than for emissions of sulphur dioxide. Refineries are now being targeted as one of the major sources of this pollutant.

Sulphur dioxide has gradually emerged as a major focus for governments in attempting to control ambient air quality. It has been shown to be responsible for an array of adverse respiratory effects, including airway inflammation in healthy people and increased respiratory symptoms in vulnerable groups such as children and the elderly and especially people with asthma. Initial attempts to control SO_2 emissions focused mainly on the power industry as the largest emitter, especially from coal-burning power plants, in order to deal with the phenomenon of 'acid rain', but as the power industry has cleaned up its act with the installation of scrubbing systems and a switch in some countries to other feeds like natural gas, so the regulatory focus next shifted to ambient air quality in cities as a result of vehicular emissions of sulphur oxides, leading in turn to the progressively lower sulphur content standards for fuels that we are all familiar with.

More recently, however, with these major sources largely dealt with, so the regulators' emphasis has begun to shift again, now back towards stationary sources of SO_2. Sulphur dioxide has been chosen in this case to represent all SOx emissions, since it makes up an estimated 97% of all SOx pollution, according to the World Health Organisation. There have already been considerable improvements in SOx emission reduction from stationary sources, but while the State of California estimates that SO_2 emissions form stationary sources fell from 132 t/d to 59 t/d over the period from 2000 to 2015, because emissions from mobile sources fell from 148 t/d to 19 t/d over the same period, so stationary sources now represent 75% of the state's SO_2 emissions, as opposed to 45% in 2000, and oil refineries account for the bulk of these stationary source emissions.

Standards for SO_2 levels in ambient air vary quite widely globally, but the most influential standard has been set by the World Health Organisation, which in 2005 set guideline values for SO_2 levels which anticipated an eventual reduction to 20 µg/m³ for a monitored 24 hour average, via intermediate targets of 125 µg/m³ and 50 µg/m³, and a maximum average of 500 µg/m³ for a short (10 minute) exposure. A number of countries have moved to the WHO's first interim 24 hour standard. In Asia, for example, these, include Hong Kong, Vietnam, Pakistan, and South Korea. India is close to the second interim target, and Singapore is moving towards the final target.

European standards

European SO_2 emission standards are subject to a bewildering variety of controls. The general limit is 125 µg/m³ for a 24 hour exposure and 350 µg/m³ for a 1-hour exposure. However, for refineries the European Commission ruled in October 2014 on the best available techniques (BAT) which were to be employed under the Industrial Emissions Directive (IED) – Directive 2010/75/EU, which sets a sector-specific BREF (BAT REFerence document) containing information about the sector and the latest emission control techniques used. Binding BATs include specified BAT Associated Emission Levels (BAT-AELs) which feed through to Emission Limit Values (ELVs) for sites.

US standards

The US used to set a National Ambient Air Quality Standard (NAAQS) limit of 140 parts per billion (equivalent to 196 µg/m³) for a 24 hour period and 30 ppb for an annual average, with a secondary limit of 500 ppb for a 3 hour average. The NAAQS was revised in 2010, establishing a 1 hour sulphur dioxide standard of 75 ppb, with compliance based on the 3-year average of the annual 99th percentile of 1-hour daily maximum concentrations. Failure to meet the standard during that period mandates the establishment of a State Improvement Plan with three years for the offending site to bring itself into compliance. The standard is considered a 'near source' standard, with measurements taken at the boundary/fenceline of the establishment.

But over and above these national standards, some states require tighter control on SO_2. For example, in California's San Francisco Bay Area, where five refineries are clustered, the Bay Area Air Quality Management District recently passed two new regulations to reduce emissions from refineries; Regulation 12, Rules 15 and 16 to track refinery emissions, and address emission increases at refineries, with more new rules in the pipeline to achieve a 20% reduction in emissions and associated health risks by 2020 over and above current mandated standards. Phase I of this includes New Rule 9-14 for reducing SO_2 from coke calcining by adding an emission limit, and Phases II and III include draft amendments to rules covering SO_2 emissions from FCCs, refinery fuel gas combustion and refinery sulphuric acid plants, and emissions of SO_2 from sulphur plants.

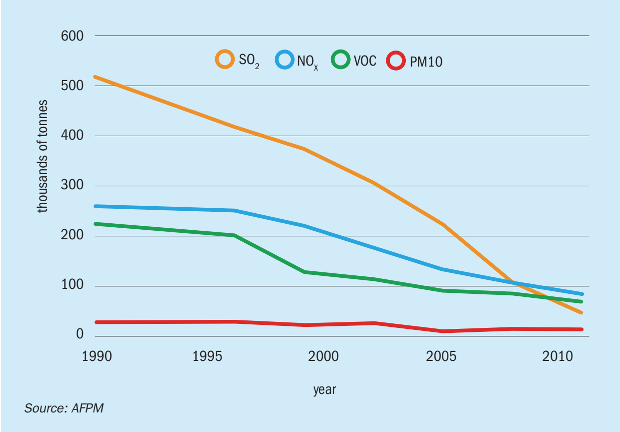
Refinery emissions

In an oil refinery, SO_2 emissions can come from various sources. A study in 2001 by European refiners' organisation CONCAWE, covering 70 European refineries, showed that the main source of SO_2 emissions at the time was from sulphur in fuel fired in furnaces and boilers, representing just under 60% of emissions. Next came fluid catalytic crackers (13.5%), which use a fluidised catalyst to contact the feedstock at high temperature and moderate pressure to vaporise long chain molecules and break them into shorter molecules. The refinery sulphur recovery unit represented about 11% of SO_2 emissions and the flare stack(s) 5%. Another 11.5% came from miscellaneous sources, including delayed coking units, used for thermal processing of heavy fractions to produce gasoil and petroleum coke.

As a result of switching to cleaner burning fuels for furnace and boiler firing, these days the fluid catalytic cracker (FCC) is generally the largest source of refinery emissions of SO_2 (as well as other pollutants such as NOx, carbon monoxide, particulate matter, and heavy metals). SRUs often routinely have a tail gas treatment unit (TGTU) to remove SO_2 and other pollutants before they are emitted to air, and can routinely achieve 20-50 ppmv levels of SO_2 in the tail gas, and sometimes lower.

Measures that have already been taken to bring SO_2 emissions from refineries under control have had considerable effect. In the United States, as Figure 1 shows, refinery emissions of SO_2 and other air pollutants have substantially decreased over the past decades, and this has occurred in spite of a move towards processing crude with greater density and increasing sulphur content. Annual average sulphur content of crude oil used by the US refining industry increased from 0.9% in 1985 to 1.4% in 2005 and closer to 1.5% by 2015. At the same time crude distillation capacity has increased slightly, from 15.6 million bbl/d to 17.8 million bbl/d, while utilisation rates have stayed relatively constant at around 90%. Nevertheless, as regulations continue to tighten, so refiners are continually having to look at ways of further reducing their sulphur dioxide emissions.

Fig 1: **Historical emissions for the US refining industry**



Source: AFPM

Remediation strategies

As noted above, one of the easiest ways for a refinery to reduce its SO_2 emissions is to burn lower sulphur fuels, generally involving switching from fuel oil to low sulphur fuel oil, LPG, gas, or desulphurising higher sulphur fuels prior to firing. However, in regions where SO_2 emission limits are most stringent, such as North America and Europe, most refineries have already made this change. The other major cluster of remediation strategies involve removing SO_2 from stack/tail gas emissions via flue gas desulphurisation (FGD). FGD systems have been installed and operated on many industrial and utility boilers and on some industrial processes for a number of years, and can remove 70-98% of the SO_2 in the flue gas, depending on the type of system and operating conditions.

FGD systems can be broadly split into once-through and regenerable systems, according to whether the scrubbing reagent can be re-used, and each of these categories can be further subdivided into wet and dry systems. Regenerative systems produce sulphur either in its elemental form or as sulphuric acid, and hence produce a useable or marketable product, while one-through systems tend to produce a waste sludge which must be disposed of. Regenerative systems have higher capital cost but lower waste treatment costs. The main types of FGD systems are shown in Figure 2.

Wet non-regenerative processes mainly include some form of line/limestone scrubbing, generating gypsum (calcium sulphate) as a by-product. These have been particularly favoured for power plant applications due to the high SO_2 removal efficiency and low costs involved. Other alkalis include sodium hydroxide (which produces liquid waste), ammonia (which produces ammonium sulphate, which can be sold as fertilizer) and magnesium oxide or hydroxide. Seawater, which is naturally alkaline and contains a mix of metal carbonates and hydrogen carbonates. There is no disposal of waste to the land, but heavy metals and chlorides are present in the water released to the sea, and of course the process is suitable only for plants at the coast.

Wet regenerative processes

The most popular wet regenerative process is the Wellman Lord process, which involves removing highly diluted SO_2 from the flue gas in the absorption section and then turning it into rich SO_2 gas in the regeneration section. In the absorption stage, ash, hydrogen chloride, hydrogen fluoride and SO_3 are removed as the hot flue gases are passed through a pre-scrubber. The gases are then cooled and fed into the absorption tower where a saturated solution of sodium sulphite is sprayed from the top onto the flue gases, which reacts with the SO_2 to form sodium bisulphite. The concentrated bisulphite is then collected and passed to an evaporation system for regeneration. In the regeneration stage, steam is used to break down sodium bisulphite. The sodium sulphite produced is recycled back to the flue gases.

Increasingly popular among other wet regenerative processes is the Shell Cansolv process, which uses an aqueous amine solution. The gas to be treated is first saturated in a water pre-scrubber and is then contacted with the amine

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solution. The amine solution is regenerated by steam stripping. A slipstream of the amine needs to be purified to prevent the accumulation of salts. The scrubbing by-product is water-saturated SO_2 gas recovered by steam stripping. Cansolv is highly selective for SO_2.

Labsorb is a regenerative scrubbing process which utilises an aqueous solution of sodium phosphate as a scrubbing buffer for the absorption of SO_2. It generates a >90 % concentrated SO_2 stream that can be used as feed to a SRU or a sulphuric acid plant. The scrubbing solution is regenerated using low-pressure steam, which virtually eliminates the discharge of liquid effluents from the scrubber.

SNOx is a regenerative catalytic process which combines a initial de-dusting stage, followed by a wet sulphuric acid and selective catalytic reduction stage, and is able to control both NOx and SOx emissions.

Dry and semi-dry scrubbing

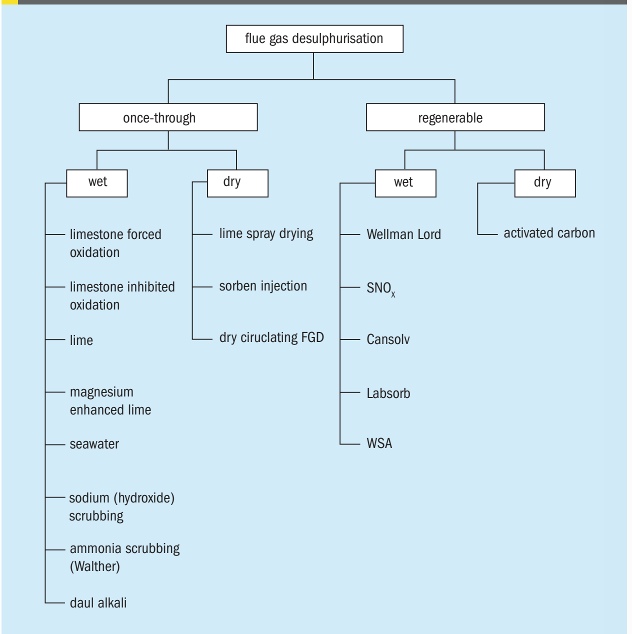
There are four types of dry/semi-dry FGD – spray dryer absorber (SDA), sorbent injection, and dry circulating FGD. Both sorbent injection and spray dryer absorber processes are non-regenerative processes. The most common choice to date for dry scrubbing has been the spray dryer absorber, which is actually a semi-dry process. In this process atomised lime slurry is sprayed into the flue gas within the reaction vessel. SO_2 reacts with the slurry to form calcium sulphite ($CaSO_3$). A part of this reacts with oxygen to form calcium sulphate. The dried reacted particulates are collected at the downstream in an electrostatic precipitator or fabric filter. This process requires production of correctly sized lime slurry droplets and proper residence time such that the particulates are dry but well related when reaching the ESP or fabric filters. Although well-proven, this process can be difficult.

Recovery of sulphuric acid

Among the various FGD processes, DeSONOX process produces sulphuric acid as the end product. Sulphuric acid can be produced in the Wellman-Lord Process by aqueous absorption and desorption, concentration and then oxidation of concentrated SO_2 to sulphuric acid catalytically.

The wet gas sulphuric acid (WSA) technology developed by Haldor Topsoe is a popular method to remove SO_2 and recover it in the form of concentrated sulphuric acid of commercial grade. In a WSA plant, SO_2 conversion is similar to the SO_2 conversion in a conventional acid plant based on absorption, except the catalytic conversion takes place in a wet gas. The WSA technology treats the furnace off-gas directly from upstream gas cleaning plants. No further drying is required, since the humidity present in the off-gas is used to hydrate the SO_3 generated in the converter and produce sulphuric acid.

Fig 2: **Flue gas desulphurisation techniques**



Process selection

Sulphur dioxide removal solutions can be very site and process specific. The key design considerations include inlet SO_2 concentration and variation, efficiency and outlet concentration requirements, scrubbing liquor pH, liquid-to-gas ratio, prevention of scaling and plugging, liquid and gas distribution and contact, by-product handling and disposal, remoteness of site etc. Regenerative FGD processes are suitable for high concentrations of SO_2, and the concentrated SO_2 stream from a regenerative method can then be reduced to elemental sulphur with CH_4, H_2 or CO. Throw-away methods are more usually used in the power industry, with lime the most common material used. About 70% of the FGD capacity in the United States use wet lime scrubbing with forced oxidation (LSFO), wet lime scrubbing with magnesium enhanced lime (MEL), or dry lime scrubbing using conventional spray dryer absorber. Dry lime scrubbing with circulating fluidized bed absorber is more widely used in Europe. Approximately 75% of the FGD systems installed on utility boilers are either lime or limestone scrubbing.

Refineries are coming to see amine regenerative processes as among the best options, as they can be highly selective for SO_2 and equipment/process design is completely conventional. The only waste effluents are the acids, particulates and very small acid flow from heat stable salts removal.

Depending on the technique used, increasing use of SO_2 removal techniques could end up producing more sulphur or sulphuric acid. Where acid alkylation is in use this offers an immediate synergy with refinery operations. ■

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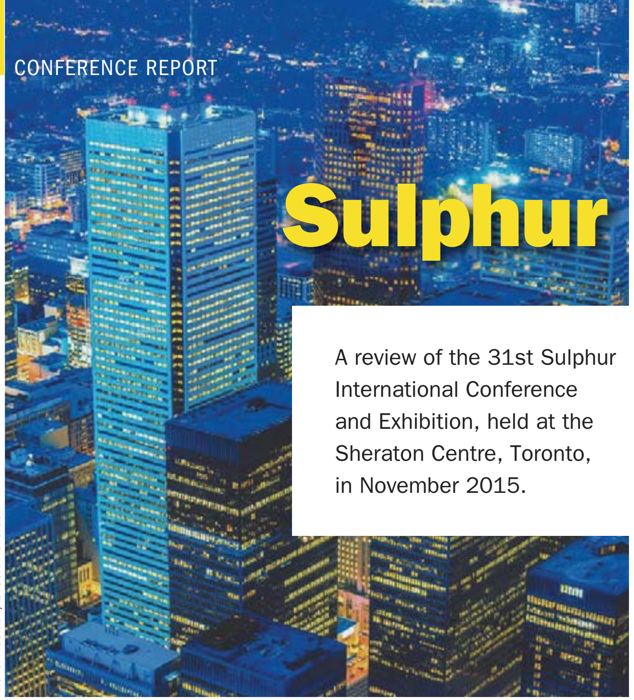

PHOTO: MBBIRDY/ISTOCKPHOTO.COM

Sulphur 2015

A review of the 31st Sulphur International Conference and Exhibition, held at the Sheraton Centre, Toronto, in November 2015.

It is a difficult time for international sulphur markets, with the slowdown in the Chinese economy coming at the same time as large new sour gas plants are starting up around the world, leading to the long-awaited fall in sulphur prices. This all no dobut contributed to the slightly subdued mood at the CRU 2015 Sulphur Conference in Montreal in November.

After an introduction from **Mike Gallagher**, CRU's new General manager for Fertilizers, **Patricia Mohr** of Scotiabank reviewed current macroeconomic developments. The recovery in commodity markets after 2009 was very rapid in spite of the recession in Europe, she said, and China pushed prices to a peak in April 2011which was almost as high as that of 2008. EU sovereign debt issues have led to a slide since then, but the sharp dip in 2015 has been due to the slowdown in the Chinese economy and the battle for market share in oil markets. Added to this has been the deflationary effect of a strong US dollar (lower prices in non-dollar markets), fears over the end of quantitative easing and rising interest rates, and worries of a 'hard landing' for China's economy.

Nevertheless, Patricia said that she believed base metal markets were likely to come up over the next two years due to supply side developments. Socita forecasts 6.9% GDP growth for China in 2015 and 6.4% in 2016 as it makes progress on its shift to a service-led economy (services now represent 49% of Chinese GDP). India is now the world's growth leader at 7.3% in 2015 and an estimated 7.6% in 2016, helped by low oil prices.

China is now pursuing what it describes as a 'silk road' policy, boosting trade to Russia and Europe via the Middle East and West Asia, and building 39 railways across the region. Looking towards e.g. vehicle sales in India, she forecast that emerging markets will help support commodity prices.

On the oil market side, Iranian oil will help keep markets oversupplied. Although US shale output is down 600,000 bbl/d on its peak, production has been very resilient. Canadian exports have likewise been up in 2016. The battle for market share is now moving into heavy sour crudes, with some production cutbacks likely by 2018.

Sulphur markets

The sulphur market overview was given by CRU's **Peter Harrison**. Sulphur is, he said, a very volatile commodity, with a price swing between $100/t and $200/t several times during 2014 and 15. The current seasonal dip has been lower than expected, but the rebound already seems to have started. There is some sign of a disconnect between Chinese port stocks and prices, as China begins to produce more domestic sulphur, but Chinese import volumes are still at 10-11 million t/a, and probably up in 2015 compared to the previous year.

The total world supply of sulphur in 2015 will be 59.5 million t/a, up 3.3 million t/a from 2014. North America is now running second to the Middle East as a supplying region, with the advent of e.g. the Shah project in the UAE. There is also more sulphur from Chinese sour gas and Turkmenistan. Looking out to 2020, supply continues to shift eastwards, with Asian supply increasing 4.5 million t/a and Middle Eastern supply by 5.4 million t/a, representing 80% of new capacity between them. Growth continues in Saudi Arabian, Chinese and Central Asia sour gas production, Conversely, there will be a continuing slide in Canadian sour gas supply, with sulphur production dropping from 2.6 million t/a to 1.8 million t/a, countered by a 1 million t/a rise in North American refinery production.

On the demand side, phosphates continue to lead, with extra production in Morocco, China and Saudi Arabia representing 4 million t/a of extra P_2O_5 demand to 2020, and globally an extra 1.5 million t/a of sulphur demand. Continuing expansion at existing nickel leaching plants could add another 0.5 million t/a of sulphur demand. But the bottom line is that the global market will be in surplus in 2015 and the surplus will increase to 3.3 million t/a in 2018 and still stand at 2.8 million t/a in 2020. Stock building is likely to take place in Turkmenistan, Alberta, Norilsk in Russia and possibly also Central Asia and Iran. Lower prices of around $115/t f.o.b. Middle East will drop to $100/t by 2019 and only rise slowly thereafter.

Isaac Zhao of CRU covered the vital Chinese market, which consumes 16 million t/a of sulphur and imports 10.7 million t/a. While fertilizers and other phosphoric acid uses consume 61% of sulphur in all forms, the industrial sector is increasingly important, with titanium dioxide, fibres, resins and hydrofluoric acid production major consumers. Pyrites still supply 23% of China's sulphur needs, with brimstone 44% and smelter acid 32%. Sour gas production and new refineries continue to increase sulphur availability, expected to increase by 3.6 million t/a from 2014 to 2018, most of that increase coming from 7 new refineries.

On the phosphate site, **Youssef Bouslikhane** of OCP gave a producers' perspective. noting that while global phosphate demand continues tog row by about 2% year on year, in Asia this is 3.7% and 2.7% in South America, offering market opportunities. However, non-integrated DAP producers currently face economic difficulties due to market volatility.

OCP meanwhile continues to push ahead with its major development programme, spending $17 billion from 2008-2025 to double its mine capacity and triple its fertilizer production with 10 integrated DAP units. Two of these are currently onstream, with the third and fourth to be up and running by the end of 2016, bossting OCP's sulphur consumption from 4.5 million t/a to 7 million t/a. The second phase, due for completion by 2020, will take sulphur consumption to 6 million t/a with another six plants. This has lead OCP to re-evaluate its sulphur purchase programme, with 1.1 million t/a of new storage for liquid and solid sulphur at Jorf Lasfar,a nd Youssef indicated that OCP was in the market for new long term supple agreements.

Acid markets

On the acid side, CRU's **Thierry Tran** asked whether 2015 was a pivotal year. There have been cutbacks in the copper sector in the US, Chile and Central Africa, focused on SX/EW production, although copper-based demand is still expected to increase to 2018. Some of this depends on the timing of the Tia Maria project in Peru, however. Asia has seen a trend towards regionalisation of the acid market, with Japan and South Korea now focusing on India as an export destination, although buyers there have seen some price sensitivity as to whether they purchase sulphur or sulphuric acid, and PPL's new sulphur burner has reduced imports. In the Philippines, meanwhile, requirements have increased but will dip with the re-start of the PASAR smelter. Asia's acid surplus will increase slightly to 2020, leading to more competition for European exporters, who are also facing more competition from Mexico for cargoes to the US, while new sulphur burning acid plants in Cuba and Namibia will also lower import demand, but the revival of the Mexican domestic copper sector could crimp acid availability from that source, and the closure of a Canadian smelter may also mean more US imports from Europe.

Steve Sackett, now managing TradeCorp Chemicals, gave an overview of the sub-Saharan African region, where increased metal production is leading to extra acid production. In 2014 the region produced 8 million t/a of acid, mainly from South Africa and Zambia, but by 2018 new smelter capacity in Zambia, Namibia and the DRC will take this to 10.7 million t/a, and demand is likely to fall short of this by 1 million t/a. Steve called this "the metal producer's curse", and looked at where the excess acid might go. In Namibia, Skorpion Zinc is converting from a sulphur burner to a roaster/smelter, while Dundee Precious Metals has also build a smelter acid plant. There is some new demand from Swakop Uranium, but moving hundreds of thousands of tonnes of acid will outstrip rail capacity. Can it be done by road? Exports are possible via Walvis Bay, but probably with negative netbacks. Zambia and the DRC have tended to be symbiotic, and some DRC sulphur burning capacity could close to take acid from Zambia, but border delays can make the cost of importing acid $130/t, and the sulphur burners supply vitally needed electricity. Some producers might end up having to neutralise acid for disposal, although new industries could be stimulated if acid becomes effectively 'free'.

Sulphur handling

Mosaic's new sulphur melter at New Wales in Florida is a game changer for the US sulphur industry. **Mark Gilbreath**, from developers Devco presented an overview of the new facility, which was in commissioning at the time of the conference. It can handle 1.0 million t/a of sulphur on a dry basis, and can handle up to 6% moisture. Modular construction has speeded the pace of the project – ground was only broken in November 2014.

The remelter gives Mosaic more options to bring solid sulphur from overseas, and the sulphur freight market was the subject for the next speaker, **Marc Pauchet** of Braemar ACM Shipping. Sulphur is mainly carried in handysize (10-20,000 dwt) or supramax (50-65,000 dwt) vessels, but represents less than 1% of the total dry bulk freight market and only 2% of the handysize market. Bulk trade is driven by the steel and coal industries, and plateauing Chinese steel production has reduced demand and led to overcapacity in the supramax size, leading to a shortening of the scrapping period to 22 years, although the overcapacity is less pronounced for handymax ships. In the longer term, bunker fuel costs due to new IMO regulations will drive freight rates upwards – the new SO_2 limits in emission control areas are especially a bigger issue for smaller ships.

Jerry D'Aquin looked at the issue of airborne sulphur during vessel discharge, reprising some of the arguments from his article in *Sulphur* 360 (Sep/Oct 2015).

Re-melting of contaminated sulphur can be one of the most challenging aspects of sulphur handing, as described by **Jim Irani** of Enersul. Some of the issues that need to be dealt with include moisture content, which can lead to acidity/corrosion, increased thermal duty, foaming etc; particulates, which can clog downstream equipment, and trapped hydrogen sulphide and residual hydrocarbons, which can lead to toxic emissions. Enersul have experience with dealing with highly contaminated (up to 30% non-sulphur) sulphur, with sulphur recovery of 90-99% and contaminant capture of over 80%, some of which can be used for road fill.

Sulphur fertilizers

Tuesday's papers closed with a session on sulphur as a fertilizer, beginning with Shell's **Peter Zissos**, who explained his company's approach to its Thiogro sulphur enhanced fertilizer technology, which encapsulates micron-sixed particles of both sulphur and sulphate to allow sulphate availability throughout the crop cycle, as sulphur is slowly oxidised to sulphate. He also explained the innovation and product development process and philosophy within Shell.

The Sulphur Institute's **Don Messick** has been an evangelist for sulphur fertilizers for many years, and he reprised sulphur's benefits, noting that in Europe there are now typical sulphur application recommendations of 20-45 kg/hectare, especially for oilseed rape, leading to 750,000 tonnes S of ammonium sulphate and other sulphur fertilizer consumption. In the US some states now recommend 20-55 kg/ha, and Canada 40-70 kg/ha for oil and legume crops. The North American sulphur fertilizer market is about 1.5 million tonnes S per year. There is also growing recognition of sulphur's benefits in India and China, where sulphur nutrient deficit

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is a large problem. The current global sulphur fertilizer market is about 10 million tonnes S, but the estimated requirement is still double that. Traditional S-containing fertilizers like TSP, SoP and AS are now being joined by a variety of complex sulphur enhanced fertilizers.

Sulphur recovery

The technical sessions were held on Wednesday and Thursday in two parallel streams, begun by **Tom Engert** of Cameron Custom Process Systems, who described the use of the *Thipoaq* biodesulphurisation system, which Cameron licenses from Paquell BV, to remove H_2S from wellhead gas in a sour gas application in Illinois. An alkaline solution removes H_2S, and the sulphide solution then reacts with bacteria in the presence of oxygen to produce solid sulphur, which is removed by filtration.

Lean acid gas applications can be problematic for Claus plants. **Benoit Mares** of Prosernat explained the use of *Smartsulf* reactors, on their own for lean acid gas applications, or downstream of a Claus plant to deal with H_2S slip. The reactor incorporates an internal heat exchanger which recovers the heat of reaction and improves the sulphur recovery rate substantially. The lean gas configuration has seen application in biogas clean-up.

Kinetics Technology has been working on H_2S removal strategies with the University of Salerno, and **Simona Cortesa** of KT presented the fruits of this research, the Catalytic Membrane Reactor (CMRS) process, which cracks H_2S to H_2 and S and removes the H_2 to drive the equilibrium, as well as recovering H_2. The novel technology is now proven at an experimental stage and is moving to a pilot plant to demonstrate it.

Amine Experts' **Mike Shellan** presented the Seven Deadly Sins of Sour Water Stripping; incorrectly designing the sour water stripper column; incorrectly controlling the overhead and acid gas temperatures; poorly managing the sour water; poorly operating or designing the flash vessel and feed stabilisation tank; inadequate removal of solids and liquid hydrocarbons, lack of a detailed sour water analysis; and neglecting the sour water stripped metallurgy. He was followed by **Giuliano LaPorta** of Siirtec Nigi, who presented a case study on an SRU with a dual stage sour water stripper system and ammonia incineration section, where the challenge was to design a system capable of handling acid gas streams with different compositions, including ammonia as the main contaminant.

Ralph Weiland of Optimised Gas Treating looked at the effect of methyl monoethanolamine (MMEA) on the performance of tail gas and acid gas enrichment units. As a highly reactive amine, its presence even in relatively small concentration (<1% w/w) can cause tremendous loss of selectivity by increasing the absorption rate of carbon dioxide. Using *ProTreat* software it is now possible to construct simulations that properly account for degradation and contamination which can reveal these potential pitfalls during the design phase rather than the more expensive option of remediation during operation.

Tail gas lines carrying Claus process gas after the final condenser stage and lines leaving air swept sulphur pits are prone to corrosion but the phenomenon is poorly understood. **Peter Clark** of Alberta Sulphur Research Ltd presented the results of ASRL studies which show that wet sulphur corrosion is inevitable below the water dew point, which could occur where sulphur build up allows insulation of the interior of the pipe from external heat. Stainless steels are far more resistant than carbon steels, however. Such corrosion can almost always be mitigated by raising the temperature and proper heat tracing.

Forough Fatemi of Jacobs Comprimo Sulphur Solutions considered the ways in which liquid sulphur can build up in a SRU, potentially leading to problems such as solid sulphur blockages, fire and equipment damage. Causes can include blockage of sulphur rundown lines by catalyst dust or debris, which can combined with sulphur to form a 'sulphur concrete', blockage in improperly designed lines, or malfunctions in the heating system. All of these can be mitigated, e.g. by paying attention to dust removal during catalyst loading, and proper design of e.g. steam heating systems.

Temperature measurement is also vital for smooth operation of the Claus furnace. **Steve Croom** of Delta Controls spoke to the advantages of two-colour pyrometry in reaction furnace temperature measurement, which can solve the problems caused by occlusion using a single colour pyrometer. The same subject was also the topic for **David Ducharme** of LumeSense Technologies, who compared eyeball/colour chart estimation, thermocouples, and of course pyrometers, and also concluded that dual detectors are better than single ones. Both speakers also argued that dual wavelength pyrometer detection was superior to dual colour pyrometry, the latter of which can be affected by changes in gas composition.

Chris Onysko of Aecometric considered design challenges for acid plant burners and tail gas incinerators in SRU plants. Failure to control temperature can lead to many problems, from inadequate ammonia destruction to shortened combustor and refractory lifetimes in tail gas incinerators. Many of these problems can be solved at the design phase, to prevent issues from occurring. By-passing clean acid gas to destroy ammonia, diverting combustion air to cool a combustor and inducing swirl in tail gas to regulate incinerator wall temperatures can be easily implemented during this phase, avoiding more expensive remediation later.

An interesting paper by **Angie Slavens** discussed the trade-off between SO_2 and CO_2 emissions. Sulphur recovery efficiency has climbed since the 1970s, from around 93-97% to 99.2%, 99.9%, and now even 99.99%. However, high sulphur recovery efficiency comes with a penalty in terms of CO_2 emissions. Taking five different cases, she showed that CO_2 emissions start to climb exponentially as you reach very high sulphur recovery efficiencies. They only increase by 20% moving from 97% to 99.9%, but there is a big jump to 99.99% for a very small gain in SO_2 recovery – up to 480 tonnes of CO_2 per incremental tonne of S recovered.

Degassing

Shell supplies its sulphur degassing technology to reduce H_2S content of molten sulphur down to below 10 ppmv. However, regulatory authorities are now also looking at the emissions of SO_2 from sulphur plants, with World Bank standards of 150 $mgSO_2/Mn_3$ often cited exiting the incinerator, equivalent to 35 ppmv in the stack gas. **Ries Janssen** of Shell Global Solutions showed that this can be achieved using its pressurised version of the technology, which allows for recycle of the vent gas without influencing sulphur run-down pressure and replaces the degassing pit with a safer pressure vessel.

A new degassing technology was presented by **James Hartman** of Controls Southeast Inc, which uses a catalyst to expedite H_2Sx decomposition (the rate determining step) without the presence of O_2. This allows use of a wider variety of sparge gases, including Claus process vapour itself. The catalytic degassing has a smaller contact zone and hence footprint than conventional oxygen degassing.

Waste heat boilers

The final papers in the sulphur recovery section concerned waste heat boilers. **Mark Welters** of Innalox presented his company's patented two piece system (TPS) of ferrules and refractory blocks for tubesheet protection which places the blocks behind he ferrules instead of surrounding them, acting like a flexible blanket to protect the tubesheet. The blocks have an overlap to prevent gases or radiation by-passing them.

Finally, **Elmo Nasato** examined the impact of waste heat boiler design on its operation and reliability, including mechanical considerations, tube to tubesheet welds, start-up procedures, steam quality, boiler feed water composition, boiler water blowdown and ceramic ferrules.

Metallurgical acid

The sulphuric acid section of the conference began with two sessions on metallurgical acid production. **John Orlando** of Noram Engineering & Constructors noted that the concentration of SO_2 in feed gas to a metallurgical acid plant can vary form 6-13%, occasionally reaching concentrations below the autothermal limit and leading to incomplete conversion and increased SO_2 emissions. He proposed a skid-mounted sulphur-burning system as an ado-on to generate additional SO_2 at such times. This can also provide a solution for SRUs, using SO_2 to convert H_2S to S and boost capacity.

Haldor Topsoe has made an improvement to its wet gas sulphuric acid process for metallurgical acid plants, as described by **Morten Thellefsen** of Haldor Topsoe. An improved heat exchange layout replaces the molten salt system with a combination of gas/gas heat exchangers and a high pressure steam system. The new layout improves process control and plant operation, he said, especially for fluctuating flows and SO_2 levels.

Fluctuating SO_2 feed levels was also the topic for **Colin Bartlet** of Outotec, in the light of declining sulphide ore grades worldwide, which often also bring higher impurity levels in terms of mercury, arsenic and halides. He presented case studies to show a range of solutions to these issues.

Kansanshi Mining in Zambia has installed a new metallurgical acid plant as part of its new copper smelter. **Douglas Louie** of DKK Engineering and **Stefan Mohsler** of Outotec took delegates through the plant design concepts and construction and commissioning of the facility. Smelter start-up occurred successfully in March 2015.

On the SO_2 emission side, **Laurent Thomas** of Shell Cansolv looked at the combination of Bayqik and Cansolv scrubbing technologies and the synergies that exist between the two processes for reducing SO_2 levels in off-gas.

Finally, **Kieber Jurado** of the Southern Peru Copper Corporation's Ilo plant gave an operator's eye view of metallurgical acid production. The No1 acid plant, with a design capacity of 525 t/d, has been expanded to 1,050 t/d, and a future expansion will take that to 1,690 t/d, as well as converting it to a 2:1 double contact- double absorption (DCDA) configuration.

Sulphuric acid catalysts

Two papers concerned sulphuric acid catalysts. Via computational fluid dynamic (CFD) modelling, **Christina Schmitt** of BASF highlighted new developments in BASF's acid catalyst pore structure and geometry to ameliorate pressure drop in environments with high dust accumulation.

Per Sorensen of Haldor Topsoe concentrated on acid converter start-up, when emissions can be at their highest, and steady state models inadequate guides to plant performance. In order to improve predictive modelling, a semi-empirical mathematical model has been set up for an SO_2 converter with parameters adjusted to both dynamic and steady state conditions. He compared model simulations with operating data from real world acid plants.

Acid plant operations

The final sulphuric acid papers on Thursday began with a strand on heat recovery. **Stefan Braeuner** of Outotec considered the trade-offs in installing a heat recovery system in a hypothetical 4,500 t/d acid plant for increased energy efficiency. The process can show a return on investment within 2.4 years, although it involves the generation of hot sulphuric acid, which brings additional technical risks, and potential equipment failure rates must also be built into the calculation.

Matthew Viergutz of DuPont MECS looked at trends in acid plant design over the past 30 years, including cost-effective wet gas processes for small plants, and the converse move to very large scale double absorption plants to achieve economies of scale. Tightening emissions legislation is now also changing plant design, while energy recovery and on-stream time affect operating expense. MECS believe that their new *Maxene* design is able to synthesise these trends into an integrated solution, and it has begun basic engineering on its first grassroots Maxene plant.

Robert Buckingham of General Atomics presented a study of a sulphur-burning turbine using exergy analysis. He showed that the turbine combustion can lead to much higher electricity generation than conventional sulphur burning, and proposed sulphur as an energy carrier, storing energy recovered from solar power and then burning it to generate power when needed.

Herbert Lee of Chemetics considered the merits of anodic protected stainless steel vs non-anodic protected silicon alloy stainless steel in a sulphuric acid cooler. Alloy coolers are costlier for larger cooler sizes, but have better corrosion resistance at higher acid temperatures or cyclic temperature variation.

Brian Lamb of MECS presented case studies in next generation furnace designs for sulphuric acid plants, using technologies like *VectorWall* and CFD modelling to craft customised solutions to meet individual needs.

The last paper was taken by **Leonard Friedman** of Acid Engineering and Consulting, who showed the damage that can be caused by hydrogen explosions in acid plants – 15 in the past 15 years, as compared to only one incident in the 30 years before that. Hydrogen is generated by weak acid corrosion and builds up in stagnant areas of the plant. Single absorption plants avoided this issue but the move to double absorption plants means there is less of a draft through the plant to remove hydrogen, while a switch to e.g. shell and tube heat exchangers allows water leaks into the acid. To ameliorate the problem he suggested eliminating stagnant areas where the H_2 can build up, reducing the surface area available for corrosion, and detecting water and steam leaks early on. ■

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The Shah project

An overview of the huge Shah sour gas project, which came on-stream last year, producing up to 3 million tonnes per year of additional sulphur.

The largest development in the sulphur industry last year was the start-up of the massive Shah sour gas project. Shah and other similar projects in and around the Arabian Gulf region have the potential to radically change the global market for sulphur.

Abu Dhabi

The rationale from Abu Dhabi's side is a fairly simple one – the Emirate is short of gas. The UAE as a whole produced 57.8 bcm of natural gas in 2014, virtually all of it from Abu Dhabi. However, consumption, led mainly by the rapidly growing cities of Abu Dhabi and Dubai, was 69.3 bcm. Ten years ago the UAE was a net gas exporter, and it still exports 8 bcm per year from the Das Island LNG terminal (see Figure 1). However, in return it has to import 18 bcm per year of natural gas along the Dolphin pipeline from Qatar. Historically most of the UAE's gas output was associated gas from oil production, but not only is the supply of this limited, it is also controlled by OPEC quotas. Therefore, like neighbouring Saudi Arabia and Oman, in order to generate new gas to run power plants, the country has been forced to look deep into the desert, where there are large, deep gas fields of highly sour gas. The first of these earmarked for development has been the Shah field, but there are other large fields at Bab and elsewhere (Hail, Shuwaihat).

Shah

The Shah gas field, around 210km south-southweest of Abu Dhabi, was first discovered as long ago as 1966. It is part of a large gas-bearing formation 60km by 11km, although Abu Dhabi does not quote its reserves separately. As the gas was found to be highly sour (23% H_2S), it was left to lie under the desert. Abu Dhabi's change of heart came in the mid-2000s, and the government began casting around for a development partner to provide technical expertise in sour gas recovery. Bids for the Bab and Shah gas field developments were sought in April 2007, but companies were reluctant to bear such a large technical and environmental risk, and so the two projects were separated out, with Shah tendered first, in August 2007. Four pre-qualified companies tendered for the overall project; ConocoPhillips, Occidental, Shell and ExxonMobil. In 2008, a 3D seismic survey was conducted of the field and three appraisal wells were drilled between 2006 and 2008. Technical studies were carried out by Shell and ExxonMobil, while the conceptual study was carried out by Fluor Corporation.

The scope of the project was decided during FEED to cover 32 sour gas wells at full production, producing 1,000 million scf/d of sour gas, with a gas processing plant to extract a nominal 500 million scf/d of sales gas (as well as 23% H_2S, the raw gas also contains 10% CO_2). In addition the project would produce 4,400 t/d of natural gas liquids, 33,000 bbl/d of condensate, and 9,200 t/d of sulphur (3 million t/a). The four sulphur recovery units – the largest in the world – to process the 1 billion cfd of sour gas would each have a capacity of 2,500 t/d of sulphur production.

In July 2008 the Abu Dhabi National Oil Company (Adnoc) sighed a $10 billion development agreement with ConocoPhillips, and a year later the parties agreed to share the project cost via a new joint venture company which would set up the project, in which Adnoc would have a 60% stake and ConocoPhillips 40%. In April 2010, however, in the wake of the global banking crash ConocoPhillips decided to end its partnership in the Shah gas project as part of the company's shift in focus from downstream and midstream activities towards upstream exploration and production.

Fig 1: **Abu Dhabi's gas processing facilities**

In the meantime, the front end engineering and design (FEED) study for the project was completed by March 2009 and individual optimisation studies for the field's sour gas reserves were carried out by Occidental and BP. Adnoc completed negotiations with Occidental Petroleum in early 2011, and formed a new joint venture company, Al Hosn Gas, to develop the project. Because all of the preliminary work had been done at this point, construction was able to begin almost immediately.

The completed Shah facility, Abu Dhabi.

Project development

The project was initially split into 10 packages. The first involved development of the gas gathering system, covering the development of wells, pipelines and gathering lines. Package two consisted of the gas processing plant, including includes four acid gas removal units, each with a 25% capacity, two natural gas liquid (NGL) recovery trains with a capacity of 50% each, and two condensate hydrotreater trains with 50% capacity each. Package three consisted of four sulphur recovery units with tail gas treatment units, each with a capacity of 25%. Package four covered offsites and utilities, package five gas, condensate and natural gas liquid pipelines, and package six initially included a 275 km liquid sulphur pipeline to carry sulphur from the Shah field to Ruwais via Habshan. Package seven involved the development of a sulphur terminal with a liquid sulphur storage capacity of 21,000 t/d and 11,000 t/d of granulation capacity. Storage facilities for solid sulphur and marine facilities for loading and export were to be developed under package eight. Finally, packages nine and ten covered plant roads, security fences and support facilities, and non-process buildings such as workshops, warehouses and vehicle maintenance.

Saipem was awarded the engineering, procurement and construction (EPC) contract to build the gas process plant and the sulphur recovery unit, as well as the EPC contract for the gas and NGL pipelines. Fluor licensed its sulphur recovery technology for the SRUs. However, Adnoc had a

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Fig 2: **Layout for main gas processing plant**

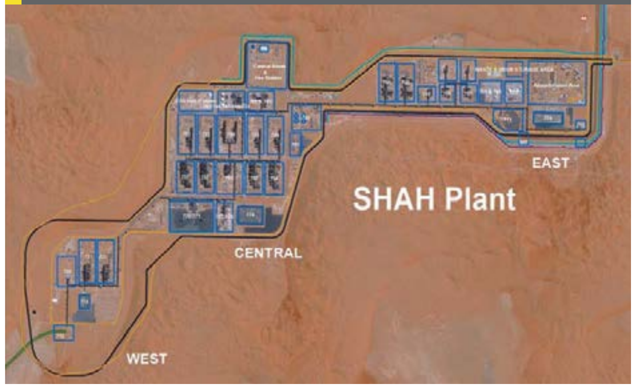

PHOTO: AL HOSN GAS

change of heart on the heated sulphur pipeline – which would have been the longest such line of tis kind in the world – and liquid sulphur facility during 2009-10, because of technical and environmental risks, and eventually decided instead that all of the sulphur from the site would be granulated at the Shah site, and then transferred by rail to handling facilities Ruwais. The decision was made easier by the parallel decision to build a rail line from Abu Dhabi to Ruwais as part of a national rail network, which the Shah line could connect to. Etihad Railway was given the contract to build the 265 km stretch of the rail line from Shah via Habshan to Ruwais. The contract for the granulation technology was awarded to Enersul, which provided 12 of its *GXM1*™ sulphur granulators and associated equipment for the sulphur plant, which is located 15km away from the main gas processing plant in order to provide additional safety in the event of a sour gas blowout. A heated sulphur pipeline connects the gas plant to the sulphur forming plant.

Technical challenges

Project development presented considerable technical challenges for the companies involved. The gas lies up to 5km down, with, as noted, 23% hydrogen sulphide and 10% carbon dioxide content. At that depth the temperature is 150°C and the pressure as high as 5,500 psi. The remoteness of the site also meant that work had to begin from scratch; building roads to allow access for a site population of 35,000 during the construction phase, who must operate 210 km from the nearest city in temperatures of 50°C.

In order to manage the risk from H_2S, the gas processing plant is split into three zones; western, central and east, with the high pressure sour gas confined to the western area. The central area holds the amine regeneration for the gas sweetening process, the sulphur recovery units and a central refrigeration section, as well as the plant control room and many of its utilities systems. The eastern area includes the natural gas liquids recovery plant, residue gas compressors, condensate hydrotreaters, chemical and product storage facilities and administrative and non-process buildings, which are deliberately placed as far from the sour gas section as possible.

Progress

EPC packages were awarded in early 2010, and the first work camp at Liwa was up and running by January 2011, at which time development drilling began. The pace picked up with the accession of Occidental to the project and by May 2011 the main access road and site preparation work and fencing was completed and the site handed over to the EPC contractors. Work was 45% complete by May 2012 and 90% of engineering achieved by June that year, with development drilling completed by July. Water and power supplies and all piping interfaces were complete by May 2013, and the project was overall 90% comnpelte at the end of 2013, with 17 wells drilled on five pads. Well drilling continued throughout 2014, and all 32 wells in the phase 1 drilling program were completed by the end of 2014, several months ahead of original plan. Meanwhile, the Habshan-Ruwais rail link was completed at the end of 2013, and the Shah gas field-Ruwais rail link by the end of 2014.

Gas production began in January 2015, ramping up to full capacity of 1 billion scf/d of raw gas by October. All gas processing trains and sulphur recovery units were operational by this date, and all products being produced to specifications.

Sulphur output

Prior to the start-up of Shah Abu Dhabi's sulphur production came mainly from the Habshan processing plant, using associated gas from the Bab and Habshan fields, which was taken to the port of Ruwais for export. Total output from these sources was about 1.5 million t/a. There was an additional 400,000 t/a from the Das Island LNG facility, and 100,000 t/a from the Ruwais refinery, for a total output of 2.0 million t/a. But the major expansions at Habshan and Shah have boosted production from the two fields to 22,000 t/d, or about 7.5 million t/a by late 2015. Etihad Rail said in September 2015 that it had already transported 2 million tonnes of sulphur to Ruwais, and that it expected to be transporting 7 million t/a during 2016. Shah alone will be responsible for 3 million t/a of this. To move it, Etihad Rail's fleet currently comprises seven locomotives and 240 hopper wagons.

Bab

With Shah now up and running, attention has turned back to the Bab project, originally slated to be developed in parallel with Shah. Like Shah, Bab has a provisional price tag of $10 billion and is aiming to extract 1 billion scfd of raw gas. The gas at Bab is even sourer than at Shah, with an average H_2S content of 33%, which will inevitably lead to more sulphur production – perhaps 15,000 t/d or more. Shell was selected in 2013 to develop the project with Adnoc, and completed a pre-FEED study early last year. A full FEED study was to have begun this year, but in January 2016, Shell announced that it was withdrawing from the project, commenting that an evaluation it had conducted "concluded that for Shell, the development of the project does not fit with the company's strategy, particularly in the economic climate prevailing in the energy industry." The company is currently concerned with its giant merger with BG. Production from Bab was tentatively set for 2020 a couple of years ago, but looks certain to slip from that date now. ■

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A complete listing of all articles and news items that appeared in Sulphur magazine during 2015.

Furnace replacement at DuPont, Burnside, Sulphur 356, Jan/Feb 2015, p52.

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Sulphur industry news

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Belgium	Work begins on Antwerp coker	Jan/Feb	11
Brazil	OCP buys 10% stake in Brazilian distributor	Mar/Apr	12
Canada	Construction complete on CCS project	Nov/Dec	11
	Fire takes Syncrude upgrader offline	Nov/Dec	11
	VMG and OGT announce alliance	Nov/Dec	11
China	Chuandongbei start-up set for October	Sep/Oct	12
Denmark	Topsoe wins award for bunker fuel scrubbing system	Jan/Feb	11
Egypt	Major refinery upgrade	May/Jun	11
	Technip to expand MIDOR refinery	Sep/Oct	15
Finland	Neste takes largest turnaround at Porvoo	May/Jun	10
France	Axens to install HDS technology in Donges refinery	Nov/Dec	12
	FMC and PROSERNAT in technology alliance	Nov/Dec	12
	Total to close La Mede, add desulphurisation	May/Jun	11
India	Bharat to double refinery capacity	Sep/Oct	15
	BPCL to press on with refinery expansion	Jul/Aug	14
	First sulphur cargo from Mangalore	Jan/Feb	11
	Gujarat refinery sulphur upgrade	Jan/Feb	11
	Paradip refinery commissioning 1Q 2015	Jan/Feb	11
Iran	Iran looks to South Pars JVs	Sep/Oct	14
	SRU at Pars phase 12 not yet operational	Mar/Apr	10
	Talks on Oman pipeline resume	Sep/Oct	14
Italy	Diesel solutions highlighted at conference	Nov/Dec	12
Kazakhstan	Funding arranged for Pavlodar refinery revamp	Mar/Apr	12
	Kashagan start-up in 2017 according to Shell	May/Jun	10
	Kashagan still aiming for late 2016	Sep/Oct	15
	Oil production at Kashagan to resume in 2016	Mar/Apr	12
Kuwait	Refinery contracts awarded	Sep/Oct	12
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Mexico	Cooperation agreement for oil and gas projects	Jul/Aug	14
	New oil and gas bonanza in Mexico?	Sep/Oct	14
	Pemex puts refinery upgrades on hold	Mar/Apr	12
Oman	Petrofac awarded contract in Oman	Jul/Aug	11
Poland	Tecnimont to upgrade Gdansk refinery	Sep/Oct	12
Qatar	Research collaboration on sour gas pipe corrosion	Jul/Aug	11
	Start-up for acid gas removal unit	Jul/Aug	11
Russia	Ammonium sulphate granulation plant	Jul/Aug	14
	Lukoil commissions SRU train	Jul/Aug	13
	Tecnimont to build Gazprom refinery	Jul/Aug	13
Saudi Arabia	Bidding under way for Fadhili gas plant	Mar/Apr	10
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	Contracts awarded for Fadhili gas plant	Nov/Dec	12
	PetroRabigh tenders for SRU	Nov/Dec	12
	Samref completes desulphurisation unit	Jan/Feb	10
	Wasit gas plant begins partial commissioning	May/Jun	10
	Wasit not yet processing sour gas	Nov/Dec	12
South Korea	Contract awarded for residue upgrading expansion	Sep/Oct	12
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UAE	Gasco awards contracts for IGD phase 3	Mar/Apr	10
	Legal challenge to IMO sulphur regulations?	May/Jun	10
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	Shah to reach capacity in 2Q 2015	May/Jun	10
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	Keystone clears Senate hurdle	Jan/Feb	10
	Keystone XL pipeline rejected	Nov/Dec	13
	Melter tank delivered to Mosaic project	Jul/Aug	11
	Permit review for Albany oil sands terminal	Jul/Aug	12
	Port Arthur reports 'operational upset'	Jul/Aug	11
	Post-conference workshop	Jan/Feb	10
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Venezuela	Sulphur output at El Palito to increase	Mar/Apr	12

Bapco awards plant contract, Sulphur 357, March/April 2015, p10.

Sulphuric acid news

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	Outotec buys Kempe smelting technology	Jan/Feb	14
	Progress on phosphate mine	Nov/Dec	16
	Rare earths leaching project passes approvals stage	Mar/Apr	14
	Ravensthorpe nickel mine closed after acid spill	Jan/Feb	14
	Ravensthorpe to operate at 70% capacity	Mar/Apr	14
	Study prefers nitric acid for leaching	May/Jun	14
Botswana	BCL studies sulphuric acid plant viability	Jan/Feb	16
Brazil	Cash raised for Tres Estradas feasibility study	Sep/Oct	20
	MBAC considering mothballing Itafos	Mar/Apr	15
Canada	Agrium considering selling phosphate business	Jul/Aug	16
	Arianne in cost-cutting exercise	Mar/Apr	14
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	Arianne secures deal with First Nations	Jul/Aug	16
	Converters in place for Clean AER project	Sep/Oct	18
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	Outotec buys Kovit Engineering	Sep/Oct	18
	Potash Ridge acquires SOP project	Sep/Oct	18
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Chile	Antucoya delayed into 3Q	Sep/Oct	16
	Mines reopen after floods	May/Jun	12
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	Outotec to upgrade Porterillos copper smelter	Jan/Feb	14
China	BASF to build electronics grade acid plant	Jan/Feb	12
	Chinese-Israeli phosphate joint venture	Jan/Feb	12
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	ICL in Chinese joint venture	Nov/Dec	14
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Jordan	Jifco plant inaugurated	Nov/Dec	16
	JPMC concludes acid agreement	Mar/Apr	16
	JPMC signs export deal with India and Serbia	Jan/Feb	15
Kazakhstan	First delivery from Eurochem phosphate mine	Nov/Dec	16
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Morocco	OCP takes £1 billion debt facility for expansions	May/Jun	12
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Namibia	Bannerman reports successful leach trial	Sep/Oct	16
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	Permit refused for offshore phosphate mining	Mar/Apr	14
Norway	Major titanium dioxide project gets approval	May/Jun	14
Peru	Focus studying Bayovar expansion	May/Jun	12
	Outotec to provide gas cleaning for zinc refinery	Jan/Feb	12
	Southern Copper "abandons" Tia Maria copper project	May/Jun	12
	Tia Maria delayed but still continuing says SCC	Jul/Aug	16
Rep of Congo	Cominco optimistic about Hinda	Jul/Aug	17
Russia	Acid plant commissioned at uranium mine	Nov/Dec	17
	CFIh buys Giprochim	Jul/Aug	15
	Copper smelter modernisation	Jan/Feb	16
	DuPont holds acid emissions technology seminar	Sep/Oct	21
	In-situ uranium leach to begin next year	Mar/Apr	15
	Russia moves to Euro V standard	May/Jun	14
Saudi Arabia	Rail wagons contract signed for Ma'aden	Nov/Dec	16
	Waad al Shamal on track for 2016	Mar/Apr	16
Senegal	Minemakers buys Baobab phosphate project	Nov/Dec	16
	ZChP to build phosphoric acid plant in Senegal	Jan/Feb	16
South Africa	Elandsfontein awards phosphate contract	May/Jun	13
	Montero moves to pre-feasibility study	Sep/Oct	16
S America	Outotec to deliver solvent extraction technology	May/Jun	12
Syria	Islamic State in charge of phosphate mine	Jul/Aug	16
Tajikistan	Loan for construction of acid plant	Mar/Apr	15
Togo	Strike at phosphate mines	Jan/Feb	15
Tunisia	Phosphate production down again	May/Jun	14
	Phosphate trains collide in Gafsa	Jan/Feb	16
Uganda	Chinese joint venture for phosphate development	Jan/Feb	14
USA	ASARCO required to remediate SO_2 emissions	Nov/Dec	14
	Cardero in restructuring to develop copper leach	Sep/Oct	20
	Construction nears completion on gasification project	Sep/Oct	18
	Delays for Paris Hills phosphate project	Mar/Apr	16
	Fibreglass acid rank trailer	Nov/Dec	14
	Florence leaching project clears environmental hurdle	Jan/Feb	15
	Freeport looking at job cuts	Sep/Oct	20
	Mosaic settles over waste allegations	Nov/Dec	14
	Mississippi Phosphates idles DAP production	Jan/Feb	15
	Uranium recovery from phosphoric acid	Mar/Apr	16
Uzbekistan	Acid capacity to increase 40%	May/Jun	13
Vietnam	Vietnam approves new SSP plant	Mar/Apr	16
World	Copper majors cut production, jobs	Nov/Dec	14
Zambia	CCM forced to stop production over pollution	Nov/Dec	17
	FQM says smelter production is ramping up	Jul/Aug	17

Kansanshi smelter ramping up, Sulphur 359, July/August 2015, p17.

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Sulphur burning optimisation

Optimum equipment for sulphur burning in sulphuric acid plants is not a trivial matter. However, owners and operators can benefit from technology providers with deep knowledge of the process, command of cutting edge analysis tools, and the ability to integrate analytical results with robust equipment designs. Thus, when analysed by the right industry experts, facility owners can realise improvements that meet and even exceed their goals.

The sulphur furnace in a sulphur burning sulphuric acid plant is generally a large horizontal cylindrical vessel of carbon steel, lined internally with refractory brick. Air and liquid sulphur are fed into the furnace via a sulphur gun equipped with an atomising spray nozzle or a rotary cup burner. The internals of a sulphur furnace are important to ensure complete combustion of sulphur to sulphur dioxide. The reaction is highly exothermic resulting in a large temperature increase. A waste heat boiler downstream of the furnace is used to remove much of the heat of combustion.

The design of the sulphur furnace must achieve good gas mixing and full combustion of sulphur prior to leaving the furnace and entry to the boiler section. Sulphur droplets impinging on the baffle or checker walls will vaporise immediately and burn to sulphur dioxide. Any unburned sulphur that impinges on the carbon steel surfaces of downstream boilers, ducting and heat exchangers will corrode the steel.

Understanding spray technology

When producing sulphuric acid from molten sulphur, it is critical that the sulphur is atomised into sprayed droplets such that combustion occurs efficiently and within the design parameters of the furnace. Each furnace is designed to accommodate a particular throughput of sulphur to oxidise into sulphur dioxide; however, the form or the size of the sprayed droplets produced becomes a major factor in determining when this combustion occurs.

The spray nozzle needs to handle a bulk mass of fluid that is delivered through it at a specific pressure drop. When this mass of fluid exits the nozzle, it is then converted into a predictable drop size spectrum with a specific spray coverage or distribution inside the furnace. The drop size and coverage required depends on the performance characteristics of the furnace. These include the length and width of the furnace, heat load, amount of oxygen for combustion, placement of baffles, and flow rate of the air through the furnace.

Spraying Systems Co. spray nozzle types

Spray nozzles can be split into two broad categories, either hydraulic or pneumatic (also called air atomising or two-fluid nozzles). Hydraulic spray nozzles use only the liquid back pressure to determine the flow rate, spray pattern, and droplet atomisation. Pneumatic spray nozzles use an additional fluid, typically compressed air, to provide primary liquid breakup. Hydraulic spray nozzles can be further classified into spray pattern types such as hollow cone, full cone, and flat spray patterns.

For sulphur burning, the most common types of nozzles are hollow cone hydraulic nozzles and pneumatic since these typically have larger free passages and create smaller droplets than the other nozzle styles.

The BA sulphur burning nozzle is a commonly used hollow cone spray nozzle for sulphur burning. It produces small to medium size droplets, has a fairly large unobstructed flow passage to minimise clogging, and has a relatively low cost to operate as compared to a pneumatic nozzle since it does not require compressed air.

Pneumatic spray nozzles require compressed air to provide primary atomisation. The liquid and the gas can meet either inside or outside of an air cap depending on the design chosen. Pneumatic nozzles can create either a flat spray or a round spray pattern, and they produce the smallest droplets of any of the conventional spray nozzles.

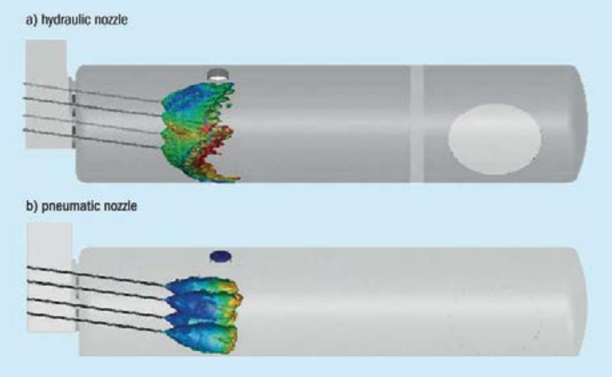
Common problems

Common problems associated with molten sulphur spraying include spray atomisation, turndown, plugged nozzles, and sulphur gun design.

The reason that atomisation and drop size is so important is that it directly affects the rate of heat transfer between the combustion gas and the sulphur. Too often, spray nozzles are chosen based mostly on their flow rate instead of on their performance. Drop size affects overall surface area. For example, by merely breaking up a single 500 micron droplet into several equally sized droplets of 100 microns each, the surface area can be increased by almost 500%.

However, this is not the way spray nozzles operate. They do not create 100% equally sized droplets. The sprayed volume comprises many different size droplets that make up the drop size spectrum. The volume median diameter is a standard way of characterising the size droplets that a particular nozzle will produce. However, this number is not useful when dealing with mass transfer applications such as evaporation and combustion. A more useful number is the Sauter mean diameter (D32), which is a means of relating the volume to surface area of a single droplet to the total volume to total surface area of all of the droplets. Another important drop size parameter for applications where residence time is a concern, such as the gas moving through a combustion furnace, is the maximum drop size, since it is this droplet that will take the longest to evaporate or combust. One must account for it as well. When comparing different spray nozzles, it is important to clarify which drop size parameter you are using.

Fig 1: **Cross section of furnace and spray coverage for different nozzle types**



Source: Spraying Systems Co.

Figure 1 shows the cross section of a furnace and the spray coverage of a hydraulic and pneumatic nozzle. It can be seen in Fig. 1a that the drop size from the hydraulic nozzle is large enough and the spray pattern opens up enough that wetting of the furnace bottom is a concern. None of the spray droplets shown in Fig. 1b of the pneumatic spray nozzle impact the wall and it appears that all of the sprayed sulphur is more able to be volatised. Further analysis would show that all of the sulphur was converted prior to the furnace exit.

Atomisation is key and is the critical first step as the sulphur is injected into the combustion furnace. Knowing what happens to these spray droplets and how it affects the furnace operation can be enhanced with CFD. Figure 2 shows three different furnace profiles. Fig. 2a tracks the combustion gas as it moves through the furnace.

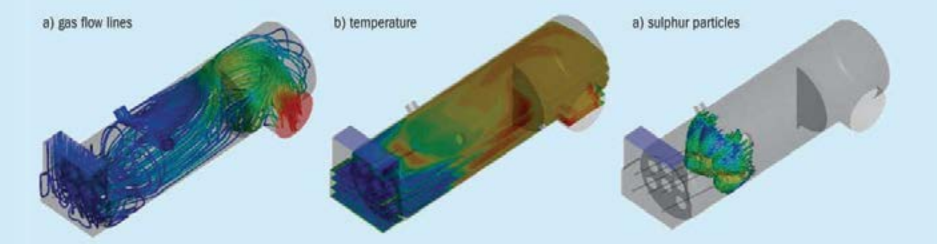
This shows what it looks like without any sulphur injected and can provide valuable information about turbulent spots and low velocity areas. This information can then be used to analyse the spray gun placement. Fig. 2b is the temperature profile with the spray guns turned on. And Fig. 2c shows the particle tracking of the sulphur itself. All of these can be used to compare actual performance with any maintenance issues or in conjunction with studies to optimise performance of the furnace. Getting to a solution is typically quicker and less costly than repeated online tests, and benchmarks can be set for future analysis as well.

Another problem that producers may encounter is spray nozzle turndown. Turndown of the nozzle refers to the effective operating range of the nozzle, or the ability to turn down the flow rate from peak flow conditions to low flow conditions.

Proper atomisation and consistent performance is required during start-up, low flow operation, as well as peak sulphur throughput. Methods used to adjust the flow rate are to use multiple sulphur guns or to adjust the operating pressure of the individual nozzles, or a combination of both. When changing the pressure to obtain different flow rates, it is important to realise that the performance of the respective spray nozzle changes as well. For instance, with a hydraulic nozzle, as you decrease the pressure in order to decrease the flow rate, drop size increases and the spray pattern or coverage collapses. Changes occur with air atomising nozzles as well; however, the changes are more subtle. This is due to the ability to alter the atomising air pressure along with the sulphur feed pressure in order to help maintain a more consistent performance across a wider range of flow rates.

Figure 3 shows a BA nozzle spraying 5 gpm and 2 gpm (upper left and lower left pictures, respectively) and then a

Fig 2: **Furnace profiles**



Source: Spraying Systems Co.

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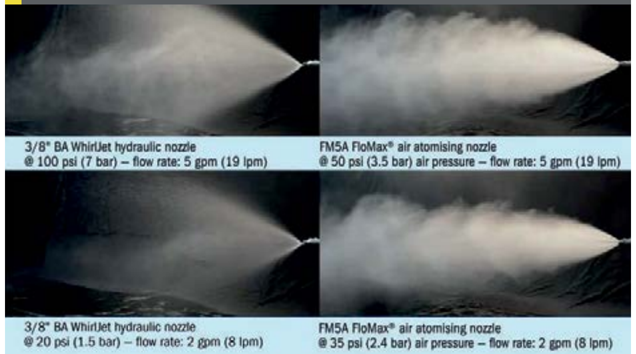
Fig 3: Spray performance



Source: Spraying Systems Co.

Fig 4: Hybrid sulphur gun

Source: Spraying Systems Co.

FM pneumatic nozzle spraying 5 gpm and 2 gpm (upper right and lower right pictures, respectively). It can be seen that as the liquid pressure supplied to the BA nozzle is reduced in order to reduce the flow rate, the spray performance changes. It can easily be seen that the spray pattern is streaky and less uniform and that there are larger droplets being produced at the lower pressure. For the FM pneumatic nozzle, the change is more subtle and no visual difference can be detected.

The performance is more consistent even at the lower flow rate and pressure. Plugged nozzles are yet another concern, and whenever there is a set orifice size, there is potential for something to build up or lodge within that orifice. This is why installing properly sized strainers upstream of the nozzle is important. However, plugged nozzles can also occur due to certain operating conditions. Contaminants, such as carsul, in the sulphur may be a problem. Also, during low flow conditions or when sulphur guns are removed, the molten sulphur no longer has the velocity it did at higher pressures/flow rates, and the molten sulphur is allowed to solidify inside the nozzle itself.

Some possible remedies are to use a sulphur gun that has a cleanout port, purging with steam or air, or use air atomising nozzles so that the atomising air pressure will continually move any low flow sulphur through the gun. Merely attempting to use the largest possible orifice can lead to poor atomisation issues with hydraulic nozzles, since larger orifices require less pressure drop, which means larger droplets and a more limited turndown.

Sulphur gun design is more of a mechanical issue, although it can affect performance if it is not designed properly. The sulphur gun must be designed to allow for thermal expansion without damaging any internal feed pipes in the gun or any joints.

Steam jackets are typically used to cool the gun and help maintain proper molten sulphur temperatures inside the gun. During the design phase, code compliance such as with ASME B31.3 is suggested, and during manufacture, certified welders should be used and relevant non-destructive examinations should be performed. Furthermore, there are sulphur guns that provide operators the ability to use either a pneumatic spray nozzle or hydraulic, which provides the flexibility to conduct testing with minimal changeover time and less cost than purchasing a second gun. Figure 4 is an example of a spray gun that is designed to ASME B31.3 specifications and has a steam jacket. The bellows is used to allow for thermal expansion without damaging the gun internals. This particular design also accepts either a pneumatic spray nozzle (as shown) or with an adapter accepts a hydraulic nozzle.

MECS furnace design

New products, technologies, and design tools are changing the way sulphuric acid plant furnaces are designed, operated, and maintained. Modern technologies are now combining experience with sophisticated design tools. The result is a holistic view of the furnace's operation and the opportunity to craft highly customised designs, targeted at solving specific problems for owners and operators.

Capturing this opportunity requires analysing furnace designs with a combination of detailed sulphuric acid process knowledge as well as modern tools like CFD modelling, in order to obtain an in depth understanding of the challenges at hand, the process environment, and the key variables that can be manipulated. Once an analysis is complete, technology providers must make critical design choices. In doing so, it is advantageous to have access to highly customisable and adaptable technologies in order to take full advantage of the analysis that was performed.

For example, it is useful to run a CFD model to identify improvement opportunities for a furnace with three baffle walls. However, if the analysis reveals the existence of "dead zones" in the furnace, the analysis is of very little value without the existence of a tool that can solve this problem. MECS® VectorWall™ ceramic furnace internals are a highly customisable furnace technology capable of being engineered in a variety of different ways in order to align its performance with both the needs of owners and operators as well as the implications of a thorough analysis.

MECS® VectorWall™ ceramic furnace Internals are constructed from a series of hexagonal blocks that stack together without mortar and remain fully supported on all six surfaces, as shown in Fig. 5a.

Each individual block can be fitted with a vector tile in order to create custom flow patterns inside of the furnace, as shown in Fig. 5b. Thus, flow fields can be manipulated using this technology in order to create the desired combustion environment and to ultimately help facility owners to meet their various objectives.

Reduced pressure drop

CFD analysis shows that furnace pressure drops can be reduced by using a single MECS® VectorWall™ in place of a conventional baffle wall design while maintaining sufficient levels of mixing to allow for complete combustion.

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Fig 5: **MECS® VectorWall™ ceramic furnace internals**

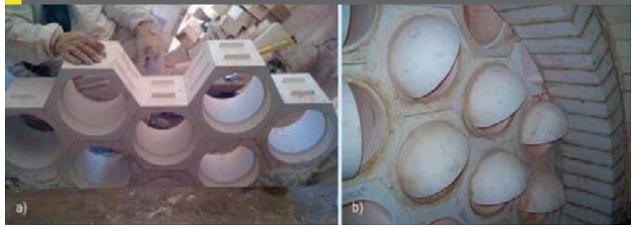


PHOTO: MECS

Figure 6 shows the typical pressure drop improvement associated with the MECS® VectorWall™ design, as compared to a furnace with a baffle wall design.

In 2015, a sulphuric acid plant owner sought a replacement for their existing furnace, and selected a MECS® furnace design, utilising a single VectorWall™ in place of conventional baffle walls. In this particular case, the use of VectorWall™ ceramic furnace internals proved to be even more advantageous than indicated by the general analysis above.

The furnace was designed to burn enough sulphur to raise gas strength and temperature in a 4.5% SO_2 stream to autothermal conditions for the converter. The roaster gas flow is split into three streams – one used as combustion "air" for the sulphur burner, and the other two mixed with the resulting hot gas upstream of the 2nd and 3rd baffle in the furnace. Each acid gas duct is equipped with a damper to control flow, and facilitate mixing. Net pressure drop of the system as a whole ranged from 15 to 25" wc.

With the VectorWall™ in place, the furnace operated well with the first damper open much farther than previously, and even the 2nd and 3rd could be opened somewhat more, while still controlling net temperature and gas strength. A temperature set point for the sulphur flow was reduced in keeping with the modified flow pattern, and the plant is still fine tuning this arrangement. An early combined pressure drop reduction closer to 10" vs. the 2" savings in the furnace alone has been observed. Temperature and gas strength control are as good as ever, and even flame stability is not compromised by the revised flow pattern. The plant is hopeful that in the long run there is a marginal capacity increase available as well.

Increased capacity

A sulphur furnace can be thought of as a plug flow reactor. Such a reactor is designed for a certain target average residence time. Thus if one can identify the total gas flow rate, the size of the furnace can then be selected to match the target average residence time. If done properly, the actual average residence time of the furnace will be equal to the target average residence time.

However, the average residence time is an average of the many different residence times that individual particles will have as they pass through the furnace. In a conventional baffle design, some particles will miss the baffles and have residence times that are less than the average; some particles will hit the baffles and have residence times that are larger than the average.

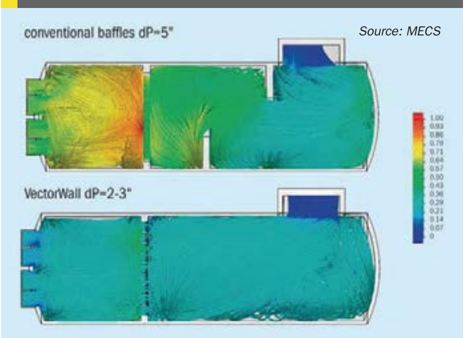
In optimising the performance of a furnace, it is useful to be able to analyse the distribution of these various residence times in order to see what portion of the particles in the furnace are exiting the furnace too quickly and what portion of the particles are in the furnace for longer than they need to be.

Figure 7 compares the residence time distribution associated with a typical brick baffle design to the residence time distribution associated with a VectorWall™ design. Note that the narrower residence time distribution associated with VectorWall™ design causes an increase in the overall furnace efficiency.

The narrower residence time distribution achieved by the VectorWall™ design indicates that a higher percentage of particles pass through the furnace in an amount of time that is closer to the design point than would have been the case with a conventional design. Thus, VectorWall™ technology can be implemented in a way that allows for higher thruput in debottlenecking projects.

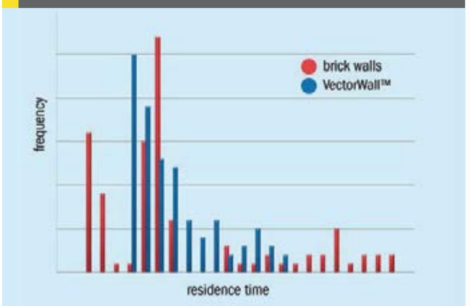
In one such case, in 2015, the owner of a sulphuric acid plant sought to replace a furnace with a larger furnace that would allow future capacity increases at the site. However, a larger furnace is more expensive, particularly for retrofits where plot space is limited and the window of time for installation is tight. In this case, a VectorWall™ design was used in order to narrow the residence time distribution and use the overall furnace volume more efficiently; the installation is currently in operation and is shown in Fig. 8.

Fig 6: **Pressure drop for 3 baffle walls vs 1 VectorWall™**



Source: MECS

Fig 7: **Residence time for 3 baffle walls vs 1 VectorWall™**



Source: MECS

Fig 8: **Recent VectorWall™ installation for narrower residence time distribution**

PHOTO: MECS

Fig 9: **MECS® HexWall™ installation**

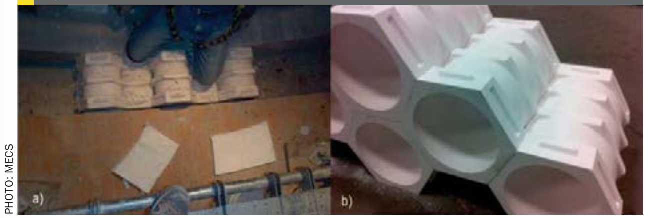


PHOTO: MECS

Reduced capital, operating, and maintenance expenditure

While it is true that the ability to eliminate furnace "dead zones," reductions in pressure drop, and reduced residence time distributions all impact the performance of an existing furnace, it is also true that these realities can impact capital and operating expenses substantially.

For furnace replacement projects at existing facilities, there are many costs that enter into the project budget. Material and labour costs associated with building and bricking a furnace are obvious elements of this equation that can be reduced using an MECS® VectorWall™ design. By using a more efficient furnace that can achieve complete combustion in a smaller space, material and assembly costs can be reduced. Table 1 shows an example of the savings that are possible with a 10% reduction in furnace volume, using VectorWall™ ceramic furnace internals to reduce installation time (thus reducing installation costs).

Less obvious furnace replacement costs include downtime, plot space, and hidden start-up costs, such as the fuel gas required for refractory cure-out.

In 2013, a sulphuric acid production facility owner sought to replace an existing furnace with a HexWall™ furnace in order to leverage many of these factors in a way that facilitated the execution of a challenging furnace replacement project on an ambitious schedule.

Due to timing and footprint constraints, the new furnace was to be fully bricked prior to the plant shutdown and then moved into place during the plant turnaround. To execute such an ambitious plan, proper planning, analysis, and mechanical stability of the furnace were key. While proper bricking is an important aspect of mechanical stability, the HexWall™ design includes additional attributes that enhance overall mechanical stability.

Conventional baffles are made out of brick and mortar and are susceptible to cracking. Thus, it is not uncommon for facility owners to rebuild conventional baffle walls on a regular basis. Additionally, the stability of a conventional brick baffle wall can vary substantially depending upon the skill of the installer.

By contrast, MECS® HexWall™ ceramic furnace internals are keyed into the brick lining of the furnace, and stacked together without mortar. The resulting furnace baffle walls are both sturdy and flexible, much like a well-built bridge. The advantage to the facility owner is a sturdier structure that can be erected in a fraction of the time it would take to build a conventional baffle wall. This results in reduced installation costs and avoided future maintenance and repair work. Figure 9a illustrates how the HexWall™ is keyed into the furnace lining and stacked together without mortar (Fig. 9b).

In this case, the facility owner was able to execute an aggressive turnaround plan which not only preserved the mechanical integrity of the new furnace, but even enhanced it. Additionally, the HexWall™ was installed in approximately one-third the time it would have taken to install conventional brick baffle walls, resulting in substantial savings in turnaround costs.

Table 1: **Capital savings for a 10% reduction in furnace size** (US Gulf Coast pricing basis)

	Price using conventional baffle design ($1,000)	Price using VectorWall™ design ($1,000)
Steel shell (materials only)	115	105
Brick lining and baffle/VectorWall™ installation (including materials and labour)	1,150	900
VectorWall™	0	150
Total	**1,265**	**1,155**

Source: MECS

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NORAM sulphur burner technology

NORAM supplies two types of sulphur burner system: pressure atomisation and air atomisation. Table 2 compares pressure atomisation and air atomisation for sulphur burners.

Air atomised sulphur burners

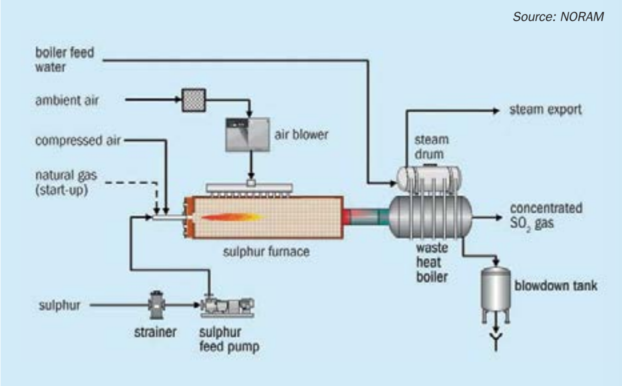
NORAM-Cellchem CF sulphur burners

The Cyclone-Flame (CF) technology was developed for systems that require small amounts of SO_2. These systems typically burn 0.5 to 8 t/d of sulphur (i.e. producing 1 to 16 t/d of SO_2).

Two sizes of the CF burners are available as standard. Practical operating capacity ranges are 0.5-4 and 1-8 t/d of sulphur respectively. At this scale, heat recovery from the sulphur combustion gases is typically not economical and a quench cooling system is normally utilised.

The NORAM-Cellchem designs can be engineered in skid-mounted sections, which reduces the total plot space required, reduces shipping costs, and allow for easy installation on site. The skid-mounted sections can be assembled and integrated into the site equipment much faster than conventional designs. One skid contains the sulphur melter, filters and sulphur pumps. Another skid contains the CF burner, the gas cooling tower, strainers, pump and cooler for the circulating water. The units have the size of a standard container.

Fig 10: **NORAM-Cellchem SO_2 production system with an SF burner and heat recovery system**



NORAM-Cellchem SF sulphur burners

The Spiral-Flame (SF) technology was developed for systems that require larger amounts of SO_2. These systems typically burn 5 to 600 t/d of sulphur (i.e. producing 10 to 1200 t/d of SO_2).

The Spiral Flame™ (Type SF) sulphur burner first introduced in 1960 required only one third of the volume of conventional burners. High-velocity combustion air is introduced tangentially to the combustion chamber, imparting a spiral path to the flame. The turbulence resulted in very effective mixing of the gas reactants, and a downstream afterburner made concentrations of up to 19+% SO_2 attainable without risk of sulphur carryover.

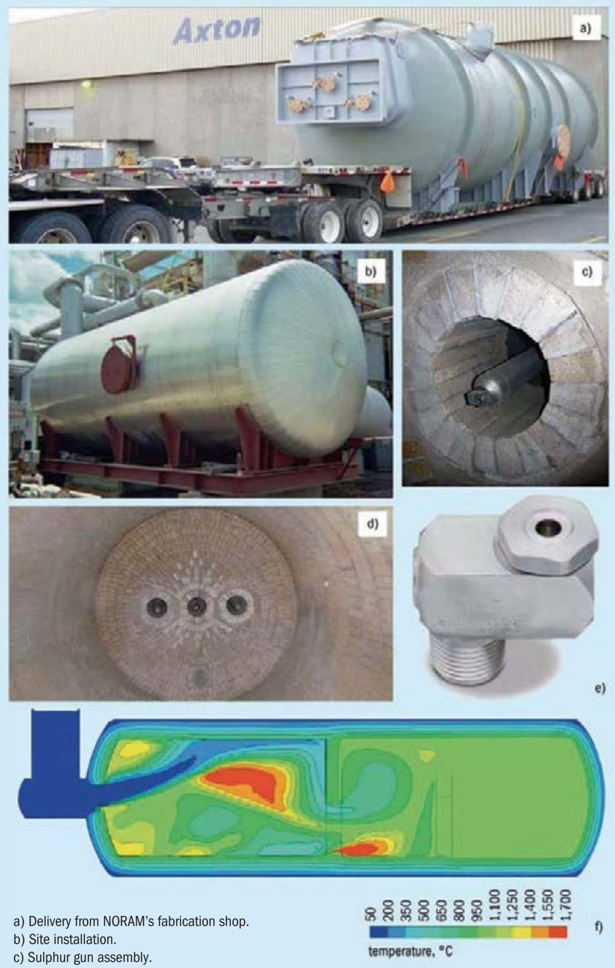
At medium scale, energy recovery can become economically attractive. When the cost of fuel is high, or when the plant site requires additional steam, energy recovery can be utilised at even smaller scales. For this reason many SF burner systems are equipped with a waste heat boiler to produce high pressure steam. This steam can be utilised for process heating or for production of electricity on site. Figure 10 shows a schematic representation of a typical SF sulphur burner system. The product is hot concentrated SO_2 gas. A quench tower can be installed downstream to cool the gas further. The system can be tailored to deliver pressurised gas or to use oxygen enrichment for maximum product SO_2 concentration.

Table 2: **Comparison of pressure atomisation and air atomisation for sulphur burners**

	Pressure atomisation	Air atomisation (CF and SF burners)
Technology	NORAM sulphur burners utilising pressurised sulphur guns	NORAM-Cellchem sulphur burners utilising air atomised nozzles
Sulphur capacity, t/d	33 to 1,000+	0.5 to 600
Equivalent SO_2 Capacity, t/d	66 to 2,000+	1 to 1,200
Equivalent H_2SO_4 capacity, t/d	100 to 3,000+	1.5 to 1,800
SO_2 concentration using air*	up to 17% SO_2	up to 19+% SO_2 using combustion air. 95+% SO_2 can be produced utilising oxygen enrichment
Required size of sulphur burner and sulphur pumps	larger	smaller
Required furnace residence time, seconds	1 to 3	0.3 to 1 seconds
Liquid sulphur pressure	7-12 bar(g)	Sulphur pressure: 1 bar(g) Atomisation is achieved by adding pressurised air at 1-4 bar(g)
Minimum turndown rate, %	70 for a typical gun. Further turndown requires multiple guns in service	8 to 12.5
Sulphur droplet diameter, mm	~ 1	~ 0.1

** Delivery of pressurised SO_2 gas is also available.* Source: NORAM

Fig 11: **NORAM pressure-atomized sulphur burners**



a) Delivery from NORAM's fabrication shop.
b) Site installation.
c) Sulphur gun assembly.
d) Refractory lining.
e) Sulphur gun nozzle.
f) Computational fluid dynamic simulation of sulphur furnace temperature.

Source: NORAM

Pressure atomised sulphur burners

Sulphur burners utilising pressure atomisation are common in the sulphuric acid industry. The pressure atomised technology was developed for systems that require large amounts of SO_2. These systems typically burn 33 to 1000+ t/d of sulphur (i.e. producing 66 to 2000+ t/d of SO_2).

Figure 11 shows some details of NORAM's pressure atomised sulphur burners.

Outotec® LURO2 sulphur burning system

The LURO burner with rotary cup technology has been a core element of Outotec's sulphuric acid plants based on sulphur combustion for more than five decades.

Recently, Outotec® LURO2 sulphur burner (see Figs 12 and 13), a new burner model has been introduced to the industry to address the changes the global markets have been undergoing for example in terms of environmental regulations and energy efficiency not to mention a constantly changing competitive landscape.

The atomisation technology with a rotary cup is completely different from traditional nozzle technology and comes with numerous advantages. The burner is fed with molten sulphur at 145°C via steam-heated piping. When it reaches the rotary cup atomiser, the molten sulphur is directed into a conical rotating cup, which is the heart of the atomiser. On the cup's inner surface, a homogeneous sulphur film is formed and atomized by an axial air stream as it leaves the edge of the cup.

On the basis of this rotary cup atomising technology the Outotec® LURO sulphur burner family comes with the following operational and maintenance benefits :

- formation of ultra-fine droplets regardless of plant load;
- uniform heat distribution;
- prevention of sulphur carry over from furnace downstream;
- elimination of steam leaks within the sulphur combustion furnace;
- easy and fast removal of burner;
- single burner configuration;
- no changes in burner configuration throughout whole operation window including pre heating phase.

These benefits have been incorporated in every LURO sulphur burner since its introduction in 1964, but current market demands and today's technology have allowed Outotec and its partner SAACKE, a German company with an 80-year tradition of providing combustion technology to the global market, to make enhancements which increase the performance and expand the burner's general capabilities.

The targeted increase in capacity was achieved through a 40% boost of the nominal sulphur burning capacity reaching

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Fig 12: **Outotec® LURO2 sulphur burning system**

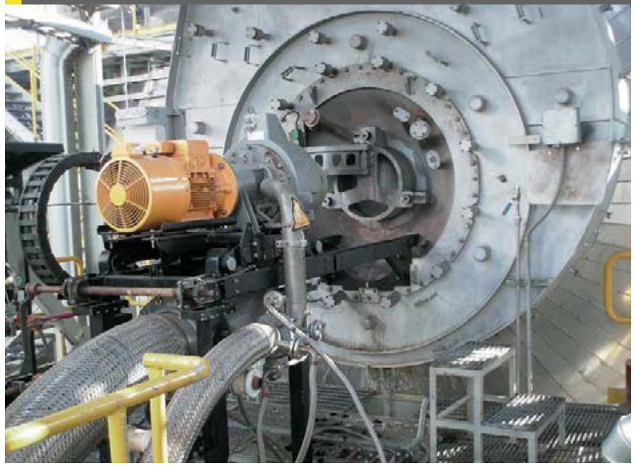

PHOTO: OUTOTEC

35 t/h of sulphur burned by a single unit.

The LURO2 can also be used during start-up processes when the sulphur furnace and converter are heated with diesel fuel. The oil atomisation during start-up is also achieved using air and the rotating cup technology – no additional equipment is needed. As an alternative natural gas can also be used as pre-heat fuel.

The burner's drive has been modified so that a flange motor is now in place with a magnetic coupling to the burner shaft thus eliminating the need for a belt drive with wear parts such as the V-belt. Replacing the rotary cup's belt drive with a frequency-controlled direct drive and a magnetic coupling device enables also the sulphur film thickness to be controlled precisely allowing an operation window with extended load conditions from 15-110%.

In addition, an automatic grease lubrication system has replaced the old oil system as well as the burner management system (BMS) associated with it to ensure a reliable and safe operation. Also noteworthy is that with the LURO there is no steam cooling inside the combustion chamber which prevents leakages.

The new burner still includes classic features such as excellent sulphur distribution and atomisation, turndown flexibility, a small combustion chamber, low sulphur feed pressure and online load changes which translate to zero down time for nozzle replacement.

Besides the enhanced burner, the system typically includes a primary air blower, pipe racks for instrument air and liquid sulphur as well as an ignition device. Completing Outotec's burner system is the BMS for the machine control cabinet, a local control box and a secondary air windbox, which helps achieve an efficient combustion at low emission levels.

Due to its atomisation of sulphur into ultra-fine droplets regardless of the plant load, the burner allows the furnace size to be minimised and limits the effects from thermal shocking to the refractory lining. Typically a LURO-equipped furnace has a 2-3 times smaller combustion chamber than a conventional one and the use of an internal baffle wall is obsolete. With its high performance in the partial-load operational range the burner requires no mechanical adjustments such as a nozzle replacement when the plant is operating at lower loads. To meet operator's plant

Fig 13: **Outotec® LURO2 burner**

PHOTO: OUTOTEC

control approach, the LURO2 burner operation can be fully integrated into a plant's DCS with the option of a supplementary condition monitoring system.

Customers who are using a lance-equipped furnace and are evaluating a capacity increase of their sulphuric acid plant will find that switching to Outotec's LURO2 burner translates to benefits in operation, maintenance and furnace size. The efficient combustion makes it possible to achieve a higher throughput with the same furnace. Thus, costs and shut down time associated with a revamp can be minimised with Outotec's LURO2 as the upgrade solution.

The windbox which has undergone a redesign and standardisation procedure is equipped with a set of guide vanes. With a small sight glass integrated it allows as supplement to the furnace sight glass the flame monitoring from the burners position. The pipe racks located on the burner platform serves for the safe media supply according to the international standards. To ensure smooth maintenance, the LURO2 burner is mounted on a moving unit allowing easy access to the rotary cup atomiser unit.

Outotec® LURO sulphur burner family main features can be summarised by:

- single burner capacity up to 35 t/h of liquid sulphur
- operational range up to 15 to 110% of the nominal sulphur load
- high operating quality also during load changes
- small furnace due to excellent atomization
- easy and fast removal of burner
- atomisation with primary air from drying tower by rotating cup.

References

1. Munro C (Spraying Systems Co): "Understanding spray technology to optimize sulfur burning", prepared for AIChE Central Florida Section (June 2015).
2. Lamb B and Ullrich R (MECS, Inc.): "Unique furnace challenges and highly customized designs", written for Sulphur (Dec 2015),
3. Mahecha-Botero A., Kyle Loutet K, Nikolaisen K, Murdock A and Cooper CG (NORAM): "Stabilization and capacity increase of sulphuric acid plants and sulphur recovery units – Use of skid-mounted sulphur burners for SO_2 supplementation", Sulphur 2015 Conference, Toronto (Nov 2015).
4. Schödde J and Storch H (Outotec): "Outotec® LURO2 sulphur burning system", written for Sulphur (Jan 2016).

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Designing for ease of future operation

A. Slavens, **L. Dreitzler**, and **S. Khan** of UniverSUL Consulting and **J. Sames** of Sulphur Experts address the design and execution shortcomings which can ultimately lead to poor sour gas treating and sulphur plant performance. Design-stage fallacies can harken back to initial assumptions used in determining the design basis for the facility when complete information is simply not available. They can also arise from poor decision-making, forced by project cost and schedule pressures. In many cases, it is purely a matter of lack of experience which can lead to design flaws that negatively impact the final delivered product, which operators must then live with for the 30+ year lifetime of the facility.

The continuous, smooth operation of a sulphur recovery facility affords minimal operator intervention, results in lowest operating and maintenance (O&M) costs and reduces the number of shutdowns required for replacement or repair of equipment, instrumentation and piping. Start-ups and shutdowns generate the most wear and tear on a sulphur plant, so minimising unnecessary trips is essential. All too often, the design, execution and construction of these plants do not take into account critical elements that will ensure the ease of future operation, opting instead for a quick and cheap delivery. Almost inevitably, this type of approach leads to designing in problems, some of which may not become apparent to the operator for many years after commissioning and are then very difficult to correct.

Most plants are expected to operate for 30+ years and many existing facilities are now into their fourth or fifth decade of operation. With old age comes experience; some good, some bad. In many cases, designs that were considered leading-edge 40 years ago are now suffering operating problems that current designs are less likely to incur because of improved understanding of the lifecycle by the designer. Operators of these older plants have learned to live with design shortcomings, but now the communication of this type of experience is filtering its way back through to designers and newer designs are implementing changes that address long-term operating problems.

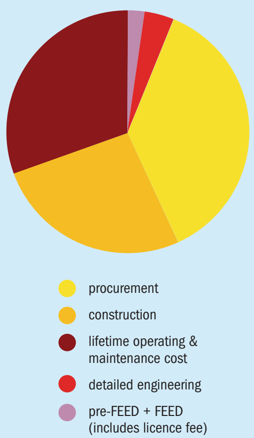
Unfortunately, designers rarely operate and operators rarely design, and as a result, there are knowledge, experience and communication gaps that occur. It is not uncommon to see the same design mistakes repeated year after year in different locations, with various clients, simply because painful operating experiences have not been fed back to project execution teams. On the flip side, it is also not uncommon for operations personnel to have a limited understanding of the complexities, challenges and pressures that occur during the execution of a large-scale grassroots development. Tradeoffs between plant flexibility and project cost/schedule must be considered, but the key is to prioritise what's most important and ensure that compromises to critical sulphur plant safety and reliability are not incurred.

Background

It is helpful to have an appreciation for basic project cost and schedule parameters which help to illustrate the complexity of a major project undertaking and which provide a context for the various design and execution shortcomings referenced throughout this article. While the primary objective of a project is to build a well-functioning plant that is safe, robust and reliable, delivery costs and schedule are huge drivers which determine how this is accomplished. Tradeoffs must often be considered.

Figure 1 illustrates the qualitative project lifecycle cost for a typical major grassroots project. A net present cost (NPC) convention is adopted throughout the article to make reference to out-of-pocket costs for the owner/operator, but the reader must keep in mind that when product sales revenues are considered, the facility will actually have a net present value (NPV) rather than cost. As shown in Fig. 1, major equipment and materials constitute the majority of project costs, followed by construction and O&M costs over the lifetime of the facility. Engineering fees account for the smallest percentage of project costs.

Fig 1: **Typical project lifecycle costs**



Major grassroots project schedules typically range from 48 to 72 months. The typical project execution schedule for a major project comprises the following stages:

- feasibility (6%)
- pre-FEED (9%)
- FEED (22%)
- EPC (57%)
- commissioning and startup (6%)

The feasibility stage is typically carried out by the owner and any necessary specialist consultants (e.g. drilling contractors or analytical testing companies) to determine whether developing the asset is an economically viable undertaking. This scope of work is often conducted prior to bringing any major engineering contractors on board. It is important to note that not every project requires a formal feasibility study phase and the duration of these activities can vary widely, depending on the complexity of the development.

The purpose of the pre-FEED stage is to address and resolve many of the questions identified during the feasibility stage and to validate the decision to continue with front end engineering design (FEED). Technology alternatives are typically evaluated during this stage and initial licensor selections are made to finalise the basic process flow diagram. Sometimes a high-level cost estimate (+/–30% accuracy) is carried out as well. The duration of this stage depends on the complexity of the development, but typical timeframe is in the range of 6-8 months.

The primary purpose of the FEED stage is to further develop the pre-FEED design to finalise and freeze the design basis for future phases of the project, as after this phase, equipment and materials purchasing will commence. In most cases, a definitive estimate (+/–10% accuracy) is developed as part of FEED, for the purpose of project budgeting and authorisation for expenditure (AFE) approval.

The primary purpose of the engineering, procurement and construction (EPC) stage is to construct the processing facility in accordance with the objectives and specifications developed in previous project phases. Engineering conducted during this stage should only be that which is necessary to develop sufficient detail for constructing the plant. Redesigning features developed during FEED should be avoided unless specific design aspects are deemed unsafe or unfit to achieve project objectives. Procurement of equipment, instrumentation, piping and all other bulk materials required for constructing the facility is carried out during this stage. Construction can be included in the EPC contract or contracted separately by the owner. For the purpose of topics discussed in this article, a single, lump sum EPC contractor is assumed. Mechanical completion (MC) is the most significant milestone during this phase, which signifies construction completion prior to the commencement of pre-commissioning and commissioning activities.

The commissioning and start-up phase of the project is normally under the responsibility of the EPC contractor, who must prove process guarantees during a performance guarantee test run (PGTR) before the plant will be accepted by the owner. Successful PGTR completion is the final project milestone before the plant is turned over from the EPC contractor to the owner's operations team. Process technology licensors also typically have involvement during the PGTR period, as their final license fee payment is tied to successful completion of this milestone.

Engineering fees make up a small portion of the overall cost associated with developing and operating a plant; approximately 10% of the total installed cost (TIC) of the facility. However, the front end engineering phases consume up to about 40% of the project execution schedule. This combination of low contribution to cost and significant contribution to schedule illustrates that it pays to invest in adequate engineering during the initial stages of the project schedule to ensure that the project design basis is finalised and frozen before moving into the next stages of execution.

Procurement and construction are the primary contributors to overall project execution costs (approximately 90% of TIC) and for this reason, it is important to finalise and freeze engineering before moving into these phases of the project. Changing specifications for procured items and/or any other basic design premises during EPC will have a major impact on cost and schedule. Changes during this stage also increase the likelihood of errors and omissions which can result from inadequate change management if a high level of diligence in communication and tracking is not maintained.

Operating and maintenance costs play a significant role in the overall lifecycle cost of a facility. In the hypothetical example shown in Fig.1, O&M costs account for approximately 30% of the NPC; however, this figure will vary greatly depending on the type of facility and level of processing required; lifetime O&M costs in the range of 40-50% of NPC are not unheard of for complex facilities. Thus, if energy efficiency measures and utility consumption costs are not carefully considered during project execution, a significant portion of the lifecycle costs are overlooked, often times without the owner even recognising the lost opportunity.

Common design and execution deficiencies

The introductory discussion, while not necessarily specific to sulphur plant design and operation, gives a basis for illustrating the various complexities and oversights that can occur throughout various stages of a project. These deficiencies can ultimately impact the end-user's ability to operate the facility and leave a legacy of poor operation that lingers for decades. Design-stage problems can result from flawed initial assumptions used in determining the design basis for a facility when complete information is simply not available. They can also arise from poor decision-making, forced by project cost and schedule pressures. In many cases, it is purely a lack of experience that leads to an inferior design. Below are some of the more common areas where execution complications occur and/or design flaws are introduced.

Decisions made solely on the basis of cost

While project implementation costs are extremely important to the overall development of an oil or gas asset, there are common pitfalls that can occur if the singular goal is to build the lowest cost facility. Prioritising cost minimisation, without regard for other project objectives, can ultimately lead to detrimental effects.

Technology license fees

Proprietary and/or licensed technologies are often required for development of an oil/gas production facility. An analysis of the various technologies available is typically carried out during the early stages of project execution (feasibility, pre-FEED and FEED) and technology selections are made on the basis of ability to achieve guaranteed product and emission specifications.

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Fig 2: **Licence fee representation, as a function of net present cost**

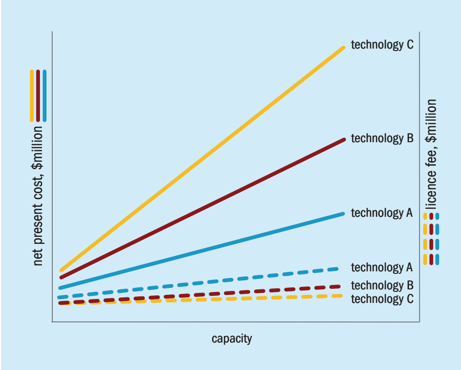
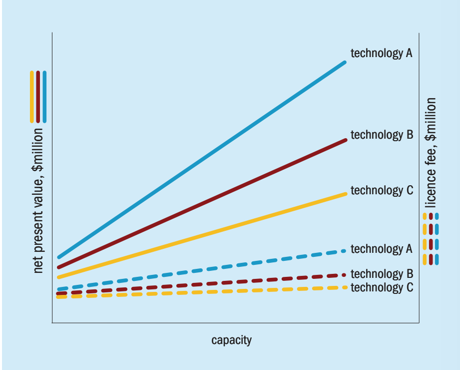


Fig 3: **Licence fee representation, as a function of net present value**



There may be several technologies that are capable of meeting these specifications, but the capital and operating costs of each may differ significantly. To truly understand which option is the most cost effective, it is crucial to carry out a full NPC analysis for each technology.

One thing that is often misunderstood about license fees is that a technology with a lower NPC advantage (or higher NPV) should demand a higher license fee than a technology which provides less economic advantage. In other words, an owner should be willing to pay more for a technology which will improve their profits over the lifetime of the development. However, if a lifecycle cost analysis is not thoroughly carried out, a license fee comparison cannot be fully understood. Ideally, the license fee should represent a percentage of the NPC the owner will save by employing the technology. This concept is qualitatively represented in Fig 2 and 3. Figure 2 shows that when comparing technologies, the lower the NPC achieved, the greater the license fee that is warranted. Figure 3 represents the same trend but with NPV rather than NPC; the technology with the highest NPV demands the highest license fee.

The key takeaway is that the license fee and/or cost of certain proprietary items associated with a technology should never be evaluated in a vacuum, but must be considered in the context of the overall lifecycle cost of the development. For example, a particular solvent for H_2S removal may be more expensive than others and/or command a higher license fee; however, if it results in a circulation rate that is significantly lower than a competitor's, the capital and operating cost savings will also be substantial. Therefore, the higher license fee and solvent cost are likely warranted. Paying a premium for superior technology can be justifiable and should be welcomed by the end-user if it results in an improvement to the overall economics of the development.

Technology selection by the EPC contractor

There are times when owners prefer to leave technology selection to the EPC contractor's discretion and thus include the licensor's process design package in the scope of the lump sum EPC bid; referred to as license + EPC (LEPC). It is most common to see this approach when multiple similar technologies or open art processes are available, as is often the case with sulphur recovery. While this contracting strategy may simplify the owner's involvement in the execution process, due to the fact that pre-FEED and FEED contracts can be eliminated, there are potential drawbacks as well.

One major concern is that there is no way to ensure that a thorough evaluation of all major technology licensors has been carried out. The owner may not see this as a serious concern when the primary goal is simply to obtain a plant that will meet process guarantees, with appropriately stringent liabilities in place as insurance. However, if the EPC contractor selects an incompetent or inexperienced technology provider, all parties will ultimately suffer when the plant doesn't perform as intended. Additionally, when the license agreement is held by the EPC contractor, the owner loses leverage with the licensor in the event that process guarantees are unfulfilled and engineering fixes are required to achieve desired process performance.

Another potential pitfall is that the preferred EPC contractor may be selected on the basis of capital cost only, without consideration for O&M costs. As shown in Fig. 1, O&M costs can make up a significant portion of the facility's net present cost and therefore require proper evaluation in order to understand which EPC bidder truly has the superior offering. In this type of situation, the owner should ask for utility guarantees from each bidder and ensure that operating cost is also taken into consideration in a lifecycle cost evaluation.

Major discrepancy in EPC bids

Figure 4 provides a breakdown of the major activities that occur during the EPC phase of a project. At the completion of FEED, a request for quotation (RFQ) for lump sum EPC is prepared, which is intended to specify design details to be included in the scope. The objective is to ensure consistency of EPC bid content. The contract is intended to protect the owner in this regard; however, the best lump sum projects are those where the contract is signed and rarely or never referenced because the contractor knows that the owner wants a robust, well-functioning plant, with all their specifications included, and the contractor has enough experience to deliver. With respect to scope definition, there are always going to be gray areas because it is impossible to include every single detail in an RFQ; this is where experience and track-record become critical.

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Fig 4: **Typical project schedule with EPC detail**

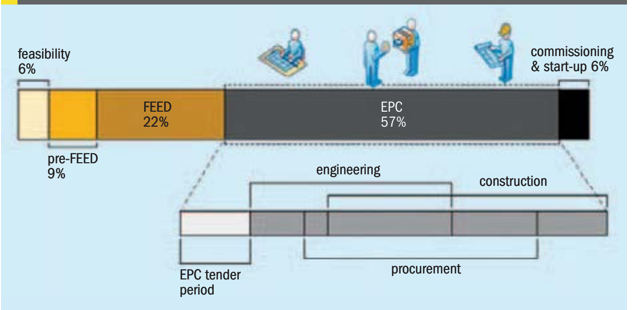

Fig 5: **SRU thermal train**

A contractor who has built several similar plants for satisfied customers has already traversed a learning curve, along with all of its associated cost and schedule challenges, while an inexperienced contractor may not know what he doesn't know and the project is likely to suffer as a result.

When lump sum EPC bids are received, a discrepancy greater than about 10% should be a flag to the owner to check and determine whether all bidders have considered the correct scope of work and made the same assumptions. Sulphur plant details are particularly important to examine, as there are many critical know-how related items that an inexperienced contractor will miss.

One of the most opportunistic areas for cutting corners to save cost is around the thermal train of the sulphur recovery unit (SRU) - burner, reaction furnace (RF) and waste heat exchanger (WHE) - which is estimated to be about 25-30% of the capital cost of a standard SRU. A small-medium size thermal train is shown in Fig. 5. This portion of the plant also happens to be one of the most critical for robust, reliable performance. Residence time in the reaction furnace and basic mechanical design details of the thermal train (burner selection, refractory design, size and number of WHE tubes, number of WHE passes, etc.) are typically dictated by the SRU licensor. However, in the case that the licensor or EPC contractor is attempting to minimise capital cost, the quality or size of these items may be compromised to still meet process guarantees during a performance test but not necessarily provide a robust design that would effectively deal with normal process upsets. Increasing residence time in the reaction furnace from the industry average of 1 second to 1.5 or even 2 seconds (for hydrocarbon and/or NH_3 burning SRUs) can increase cost significantly, as can a selection of larger diameter WHE tubes (larger diameter tubes mean a longer WHE). However, the owner would benefit immensely from this more robust design, which would minimise catalyst fouling (soot deposition), WHE tube plugging, tube/tubesheet failures and refractory repairs over the lifetime of the facility.

While the thermal train is one of the most critical areas in a sulphur plant, few systems installed as part of a lump sum EPC contract actually represent genuinely robust designs because of project cost pressures. Some of the important details that would contribute to a robust mechanical design of this system are described in industry literature[1-4].

Decisions made solely on the basis of schedule

Project schedules can range from relaxed to reasonable to extremely aggressive, depending upon the level of pre-planning that has been carried out and the motivation for project completion deadlines. While the time required to bring a development to fruition is extremely important, there are certain pitfalls that can occur if the singular goal is to complete the project on a fast-track schedule. Below are some examples which illustrate how prioritising schedule over all other project objectives can lead to detrimental effects on the facility.

Tendering EPC before FEED is complete

Figure 6 provides an illustration of the number of parties involved in each stage of project execution and shows that as a project progresses beyond the FEED stage, the number of project personnel and parallel project execution activities increase dramatically, reinforcing the need to avoid major design changes that would have a knock-on effect on a huge number of activities and procured items. During the EPC tender and contractor selection period, it is even more important to minimise changes, as any modifications to tender documents would need to be propagated to all bidding parties to ensure that the scope is consistent throughout all EPC bids. This is yet another illustration of why it is important not to short-cut the front-end engineering activities and to ensure that the design is truly frozen before proceeding on to EPC tendering and further stages of execution.

Clone projects

Plant operators often wish to copy an existing plant or unit within a plant, either inside the existing facility or as part of a new facility. In these instances, "clone" projects are often considered. However, there is rarely such a thing as a true clone unless it is just a duplicate train in an existing facility, such as a new SRU in an existing sulphur recovery complex. But even in this scenario, there is a reason why the capacity is increasing, such as different feedstock or changes to upstream processes, so an exact copy may not be possible. Even in the case that the feedstock is identical to other trains, layout and hydraulics may not be. Also, sulphur recovery efficiency (SRE) regulations may have changed in the time since the previous project(s) were carried out, requiring additional tail gas treating facilities.

For clone projects that require transferring a design from one facility to another, there is an even greater possibility for changes due to varying utility conditions, plot availability and/or client specifications. One industry technical paper[5] describes a clone project which involved copying the design of a sulphur recovery complex that had been built seven years prior, while also addressing more stringent SRE requirements. For this project, costs and schedule were optimised, but only through the project team's dedicated focus on many of the topics addressed in this article.

Licensor document reviews

Licensor review of "for construction" drawings is a requirement included in most technology license agreements, with the intended purpose of giving the technology provider a chance to review what is actually being constructed and flag any concerns that might impact the plant's ability to achieve process performance guarantees. However, due to schedule pressures, EPC contractors often don't send documents to the licensor at all, or send them too late, after the construction phase is well underway. Even when documents are transmitted at the appropriate time, licensors may not have the time or appropriate personnel available to carry out a thorough review, if the project has fallen from their radar in the time since the process design package was completed.

In either case, the intent of the review is lost, which introduces process performance risk.

Assumptions made when information is not available

During the early stages of a project it is difficult to develop a definitive design basis and objectives for contractors to work toward due to missing or unavailable information. For example, raw feedstock information may not yet be available from test well campaigns, feedstock supply agreements may not yet be finalised, final emission regulations may not yet be mandated by regulatory bodies and/or turndown requirements may not yet be known. The owner must strike a balance between meeting the overall project schedule and minimising rework. In order to keep changes and associated costs within reasonable bounds, finalisation of major design basis issues should occur before FEED commences.

The following specific examples illustrate some of the possible effects of

Fig 6: **Qualitative illustration of increasing complexity throughout project execution**

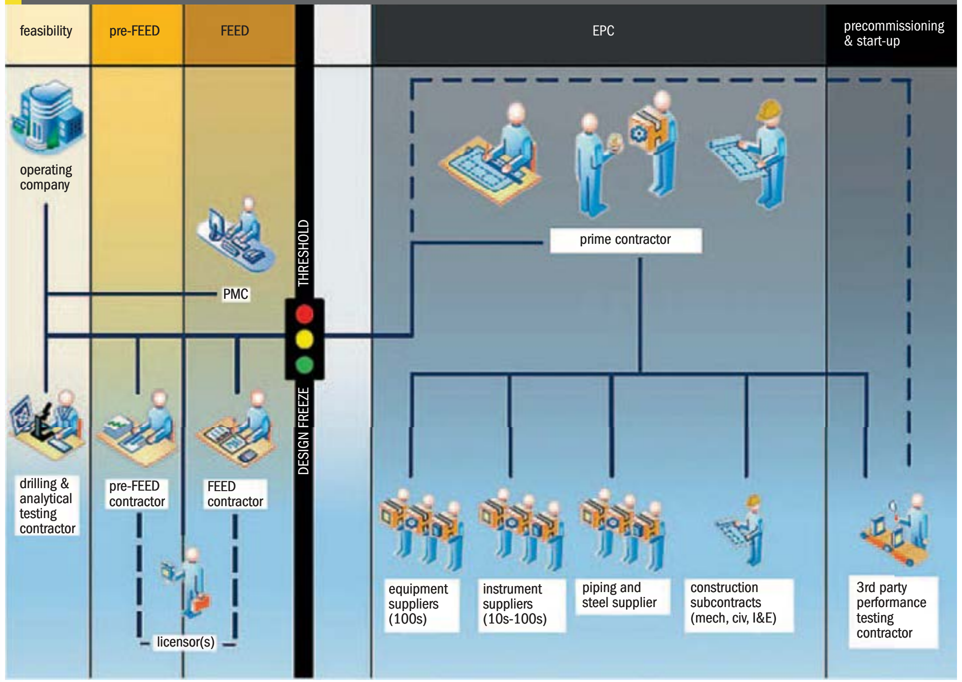

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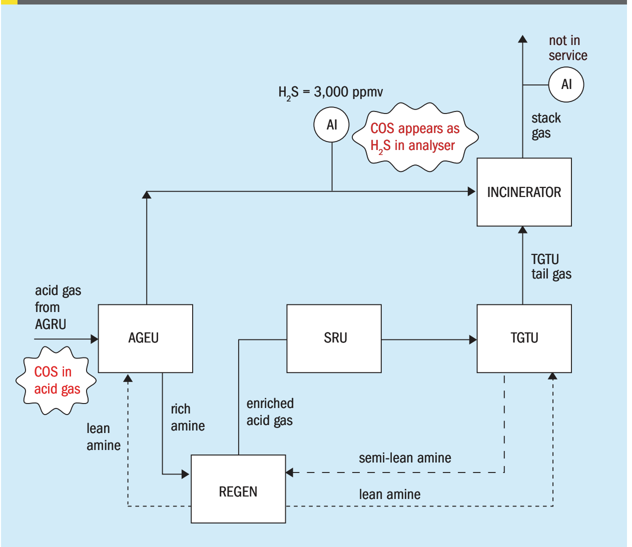
Fig 7: **Unexpected COS in acid gas**



applying incorrect or incomplete feed gas assumptions.

Unknown sour gas composition

Not all oil and gas reservoirs are created equal. Many have a fairly constant composition throughout; however, there are also many examples of stratified gas fields with varying composition, depending on the location and depth of a particular well. Development of a design basis for a gas treatment facility requires appraisal well testing in various locations in the field, thereby defining the full range of sour gas compositions that may be encountered during production. This is important for ensuring the upstream units, including the acid gas removal unit (AGRU), can meet the treated gas specification, regardless of feedstock. It is also important for operation of the SRU, which can be negatively impacted by lower than design H_2S composition. If the impact is dramatic enough, acid gas H_2S composition can drop so low that SRU reaction furnace operation is not possible due to flame instability (< ~25 mol%). Low H_2S content can also impact the ability of the reaction furnace to destroy contaminants, which can result in catalyst poisoning or ammonia salt plugging. Lower than design acid gas H_2S composition also reduces sulphur production capacity because of additional CO_2 in the feed, which consumes process volume.

Corrections for such problems can range from changes in operating schemes to complete plant redesign, depending on the magnitude of discrepancy between design and actual conditions. Accurately forecasting the full range of feed conditions and compositions is critical; a world-class plant design is useless if not designed for the feedstock it must process. However, drilling and producing appraisal wells is expensive and time-consuming; thus, a complete assessment of field compositions and conditions is rarely known at the start of a project and some level of assumption is normally required.

Unexpected COS in acid gas

In the specific example illustrated in Fig. 7, a gas plant AGRU was designed to produce a lean acid gas which would require enrichment prior to processing in an SRU/TGTU[6]. A selective amine was employed in the acid gas enrichment unit (AGEU) and TGTU. Upon start-up of the AGEU, the analyser on the absorber overhead indicated extremely high H_2S content (~3,000 ppmv vs. 40 ppmv design), despite the fact that most other indications (absorber temperature profile, rich and lean amine H_2S content and acid gas H_2S concentration) were in line with expected design conditions. The incinerator stack SO_2 analyser had not yet been commissioned and the EPC contractor was unable to obtain stack samples, so stack SO_2 concentration could not be checked.

After several days of troubleshooting, including collecting radar scan data on the AGE absorber, the presence of COS in the acid gas feed to the AGEU was discovered, which was never included in the design basis, underlining the need for comprehensive analytical data. The amine was not capable of removing organic sulphur and therefore COS in the feed slipped from the absorber through to the incinerator. The analyser was not configured to measure COS and it caused an interference with the H_2S measurement, producing a reading which was two orders of magnitude higher than the actual H_2S value. The end result was that COS slippage increased SO_2 emissions beyond the regulation limit and the SRE process guarantee could not be met. To correct the problem, COS will have to be converted to H_2S upstream of the AGEU and the operating company is currently considering options to achieve this.

If the presence of COS had been communicated in the original design basis, the SRU/TGTU scheme would have been reconsidered. It could have been designed to accommodate COS via routing the absorber overhead to a hydrolysis bed, with subsequent H_2S removal in the TGTU, or the AGEU might have been eliminated in favor of fuel co-firing in the SRU.

Unexpected BTX in acid gas

There have been several examples of sour gas plant developments in which well fluids were not specifically tested for aromatic hydrocarbon components such as benzene, toluene and xylene (BTX). As a result, the SRU designer was unaware that these catalyst-poisoning compounds would be present in the acid gas feed. In most of these cases, lower than required reaction furnace temperature results in incomplete destruction of BTX in the furnace and ultimately poisons the Claus catalyst, essentially rendering it ineffective. Overall SRE of the SRU is then only that which can be achieved in the reaction furnace (60-70%), resulting in excessive SO_2 stack emissions.

To correct the problem, various means have been employed, including BTX removal in upstream carbon beds[7] or implementation of design features aimed at increasing reaction furnace temperature,

such as fuel co-firing[8] or acid gas enrichment. Of course, it is best if the designer is aware of the presence of BTX prior to commencing engineering work so that the facility can be designed accordingly. In many cases, experienced licensors will assume the presence of BTX compounds (up to ~1,000 ppmv) in sour gas plant SRU designs, regardless of whether the design basis stipulates their presence. However, doing so can have a significant impact on capital and operating costs of the SRU.

Unknown heavy hydrocarbons in acid gas and knock-on effect

In this specific example, the owner of a sour gas development did carry out well testing to determine raw gas composition prior to constructing the amine and sulphur plants, and discovered heavy hydrocarbons of significance. Thus, the designer added a chiller at the outlet of the acid gas knock out drum, upstream of the SRU reaction furnace, which chilled the acid gas to 0°C, to condense heavy hydrocarbons. Of course this reduced the reaction furnace operating temperature, which was already going to be relatively cool when processing lean acid gas with approximately 50% H_2S. The knock-on effect which subsequently ensued is listed below:

- Significant heavy hydrocarbons were present in sour gas well fluid samples and some of these species were expected to make their way into the acid gas feeding the SRU.
- The SRU designer elected to install a chiller in the acid gas stream to reduce its temperature to 0°C and condense heavy hydrocarbons upstream of the burner.
- The process simulation showed that the reaction furnace would be lower than required for adequate hydrocarbon destruction (< ~1,050°C).
- Fuel co-firing was employed in the design to increase reaction furnace temperature.
- The process simulation showed that the formation of COS and CS_2 would increase in the reaction furnace as a result of fuel co-firing.
- Titanium dioxide catalyst was included in the first converter for improved COS/CS_2 conversion.
- After start-up it was observed that titania was not capable of adequate COS conversion, which appeared as high H_2S in the tail gas analyzer, which was not configured to measure COS.
- Additional combustion air was admitted to the reaction furnace, on automatic control, based on the high tail gas analyzer H_2S:SO_2 ratio reading.
- Off-ratio SRU operation (significantly lower than 2:1) resulted in higher than necessary combustion air flow, sulphur recovery efficiency was negatively impacted and load on TGTU increased.
- High SO_2 in the SRU tail gas resulted in insufficient H_2 in the hydrogenation reactor.
- SO_2 breakthrough to the quench column occurred, lowering quench water pH.
- Caustic was injected into the quench water circulation system to increase pH.
- Caustic overdosing resulted in high pH and inadvertent H_2S absorption in quench water.
- Regeneration of amine in the TGTU produced a recycle stream that was predominantly CO_2, which further cooled the reaction furnace temperature.
- Additional fuel was co-fired, further exacerbating the problem.

The irony (or sheer luck) of this example was that shortly after start-up it was discovered that not much hydrocarbon was being knocked out in the chiller and detailed analysis confirmed an essentially hydrocarbon-free acid gas. Thus, the chiller was deemed no longer necessary. Once the chiller was shut down, the need for co-firing was discontinued and plant operation was stabilised.

Neglecting project lifecycle considerations

During the early stages of a project, it is important to consider lifecycle objectives such as integration of flowsheet synergies (for optimised lifetime operating costs) and implementation of features that will accommodate future operating requirements. If these types of opportunities are not explored early-on, they become much more difficult and costly to implement later, as the design is progressed, equipment is purchased and construction commences.

The following specific examples illustrate some of the possible effects of neglecting project lifecycle requirements.

No amine flowsheet integration

In a sour gas development, amines are typically employed for main gas sweetening in the AGRU and for H_2S removal in the TGTU. Integration opportunities exist for reducing capital and operating costs, as well as improving the quality of the acid gas feeding the SRU[9]. Plot space reduction is another potential advantage of an integrated flowsheet. Figures 8 and 9 provide an example of a hypothetical gas plant application employing non-integrated and integrated amine systems respectively. Figure 13 illustrates that by using partially loaded amine from the TGTU in the AGRU, the number of equipment items and amine circulation rate can be reduced, optimising capital and operating costs.

Ineffective amine flowsheet integration

While an integrated flowsheet can provide advantages, the added complexity can present possibilities for design oversights if not properly considered. An integrated flowsheet can introduce limitations which aren't commonly encountered; these can be overcome but may require the designer to deviate from a business as usual approach. For example, it is common to consider relatively low end of run (EOR) SRE (92-93%) for the SRU when designing the TGTU because the only material impact on the TGTU design is a marginal increase in circulation rate, which does not have an appreciable influence on TGTU capital or operating cost. However, when the TGTU is integrated with the AGRU, increasing circulation rate in the TGTU also increases semi-lean flow to the AGRU and may negatively impact the overall optimisation of the system. Thus, an integrated design may require the TGTU designer to reduce their typical margin on sulphur recovery efficiency guarantees. Additionally, the more tightly-designed TGTU will be less tolerant of SRU upsets, meaning that operations personnel may need to more strictly control SRU operation within certain operating boundaries.

If different licensors are selected for the AGRU, SRU and/or TGTU, the process guarantee interfaces can present challenges, both during execution and performance guarantee test run. The end result is usually the compounding of licensor design margins on top of one another, possibly eroding many of the benefits of integration in the first place.

Not designing and/or pre-investing for future operations

Owners are often aware that future regulations may come to bear either during project execution or after the plant has commenced operation, and are therefore faced with the dilemma of attempting to evaluate and address these requirements at the start of the project, or waiting until

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Fig 8: Non-integrated flowsheet

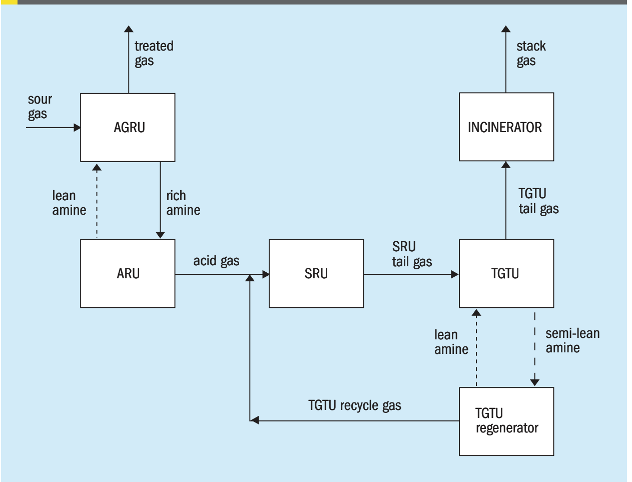
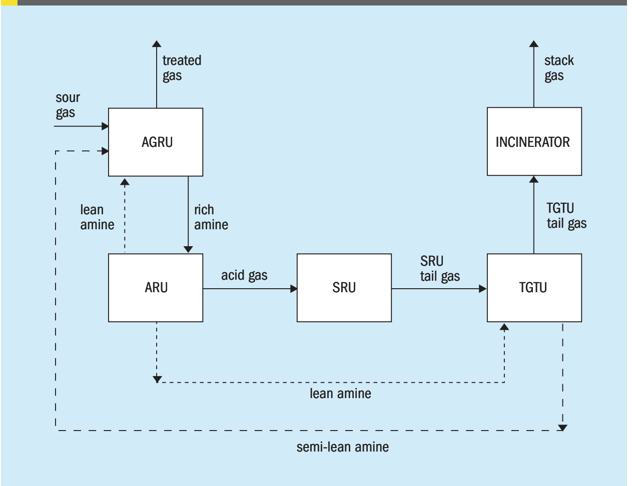


Fig 9: Integrated flowsheet



the new regulations are actually in place. The latter allows the owner to postpone investment but may also result in higher overall project costs and negative impacts on future operability and plant layout. Conversely, with a limited amount of planning and/or pre-investment during early engineering stages of a project, many of these challenges can be avoided. Some specific examples:

- Future required increases in sulphur recovery efficiency can be accommodated by including provisions for future addition of a TGTU, modifications to the selected TGTU technology and/or routing the sulphur pit vent stream to the front of the SRU.
- Future requirements for increased capacity can be accommodated by including provisions for changing out trays in existing AGRU absorber(s), adding new SRU trains and/or employing oxygen enrichment [10].
- Future CO_2 capture requirements can be accommodated through a host of provisions for future modifications, either upstream or downstream of the SRU; it is noteworthy that capturing CO_2 upstream of the SRU provides an added debottlenecking benefit by freeing up SRU capacity previously consumed by the CO_2.

If considerations for future operating requirements, such as those described above, are thought through during early stages of project development, design provisions can be included that will facilitate easier and more cost-effective transition to new operating conditions at a later date.

Neglecting considerations for special types of projects

There are certain types of projects which require a departure from standard execution practices to achieve success. Two major examples are revamp projects and those that involve deployment of first-of-a-kind technologies, both of which require special attention to detail. Because of the location of an SRU at the back end of a processing facility, revamps are fairly common, as any upstream changes will have an impact on operation of the sulphur complex. Additionally, sulphur plants lend themselves to duplication, due to the fact that a single facility will often require multiple identical trains. However, when new technology and/or configurations are required, special care should be given to ensuring that any substantial risk is not propagated across multiple trains.

The following specific examples illustrate some of the possible effects of neglecting special execution requirements required for revamps and first-of-a-kind applications.

Revamp third stage of existing Claus SRU to TGTU hydrogenation service

In this example, an existing SRU required an increase in sulphur recovery efficiency through the addition of a tail gas treating unit[11]. This type of project is performed regularly and is often not even referred to as a revamp because the TGTU is designed and constructed as a standalone unit. However, in this case, the operator was limited on plot space and was also looking to minimise capital expenditures, and therefore decided to convert the third reheater and Claus reactor in the SRU into TGTU hydrogenation service. The reactor was deemed to be of sufficient size when Claus catalyst was replaced with hydrogenation catalyst; however, the existing reheater was only capable of achieving 230°C outlet temperature, while a minimum outlet temperature of 240°C was preferred for EOR catalyst operating conditions and presulphiding. Thus, the process and mechanical conditions for this revamp project were such that routine project execution methodologies could not be followed blindly.

While it is expected that the project would have turned out to be successful, due to the diligence and focus of the project team, it was never completed because the refinery was shut down prior to project completion. Known risk areas were as listed below, all of which were being consciously mitigated during execution:

- inadequate presulfiding due to low temperature, resulting in poor catalyst performance over the lifetime of the facility;
- inadequate conversion of COS in TGTU hydrogenation reactor due to low temperature and insufficient hydrogenation catalyst activity, especially at EOR conditions;
- SO_2 breakthrough from TGTU reactor to quench column, especially at EOR catalyst conditions.

First-of-a-kind, unproven technology in multiple trains

Due to the fact that most sulphur recovery facilities require multiple trains, it can be tempting to simultaneously deploy a new technology or configuration in more than one unit, for a multi-train project. However, in one particular sulphur plant example, a new, unproven technology was employed in multiple trains and subsequently turned out to be incapable of meeting process performance guarantees. After start-up and an unsuccessful performance test, a plant modification was engineered and implemented in each train. The project incurred significant costs and downtime but eventually performance guarantees were achieved.

This example illustrates the point that it is not only the responsibility of the licensor to stand behind their process guarantees, but it is also crucial for the end-user to research the technology to ensure that its performance has been demonstrated and proven in a sufficient number of commercial references.

Missing critical design details

As stated previously, it is often a lack of experience during one or more stages of the project, which leads to the delivery of an inferior design. Table 1 provides a listing of critical sulphur plant design details that are frequently missed by inexperienced EPC contractors. While it is true that as more bells and whistles are included in the design, the cost of the plant increases, most of the items documented in the table are necessary for a sulphur plant that is robust, reliable and easy to operate. Additionally, many of these errors and omissions also possess inherent health, safety and environment (HSE) risks. Items are ranked by relative severity, in terms of impact on operations and/or level of difficulty associated with correcting the problem, with 5 being the most severe and 1 being the least.

Summary and conclusions

There is a need to strike the right balance between robust, efficient SRU operation and lowest lifecycle cost, because the reality is that project budgets are not unlimited. There is no substitute for experience, throughout all stages of project development. Prioritisation of the critical aspects of SRU plant design pays dividends through sustained, reliable operation and optimisation of project lifecycle costs. Operators who have not experienced the pain of trying to operate an unreliable unit may not recognise the value that the minor additional up-front engineering cost can offer. Additionally, owners who do not have a clear understanding of whether they have selected the lowest lifecycle cost alternative may be incurring lost opportunity costs on a daily basis without even knowing it.

Project and operations personnel must find ways of effectively communicating and understanding the other's perspective. Experience shows that when these parties are not aligned, plant reliability and operability will suffer, ultimately eroding profit margins and creating the potential for HSE risks. The key is to prioritise what's most important and ensure that compromises to critical sulphur plant design parameters are avoided.

References

1. McGuffie S., Martens D. and Demskie M.: "A robust SRU WHE design," Brimstone Vail Sulfur Symposium 2012 Vail, Colorado (Sep 2012).
2. Martens D., Porter M. and Stern L.: "Why do waste heat boilers fail?," Sulphur Magazine No. 354 (Sep-Oct 2014).
3. Piper A. and Proctor J.: "Understanding today's limiting factors on reaction furnace linings," Brimstone Vienna Sulfur Symposium 2013, Vienna, Austria (May 2013).
4. Young M., Maldonado S, Koscielnuk D., van Son M., Piper A. and Proctor J.: "Limiting factors on reaction furnace linings part 2 - A case history," Brimstone Vail Sulfur Symposium 2014, Vail, Colorado (Sep 2014).
5. Slavens A. and Didriksen K.: "A novel pairing of technologies to achieve today's sulphur emission stringency at lowest lifecycle cost," SOGAT 2011, Abu Dhabi, UAE (Mar 2011).
6. Cicerone D.: "AGE absorber troubleshooting," Brimstone Vail Sulfur Symposium 2014, Vail, Colorado (Sep 2014).
7. Crevier P., Adab A., BaAqeel H., Hummam I. and Misfer A.: "Saudi Aramco eliminates Claus catalyst deactivation caused by aromatics using activated carbon," 57th Laurance Reid Gas Conditioning Conference, Norman, Oklahoma (Feb 2007).
8. Racz A., Hughes M., Slavens A. and Street R., "Update on the start-up of the world-class sulphur recovery facilities at GASCO's Habshan 5 Integrated Gas Development (IGD)," SOGAT 2014, Abu Dhabi, UAE (Mar 2014).
9. Lamar J., Slavens A., Brok T. and Nikolic D.: "Enhanced sulfur recovery from lean acid gases reprise….the impact of the upstream acid gas removal unit," 61st Laurance Reid Gas Conditioning Conference, Norman, Oklahoma (Feb 2011).
10. Tonjes M., Hatcher N., Johnson J. and Stevens D.: "oxygen revamp checklist for sulphur recovery facilities," 50th Laurance Reid Gas Conditioning Conference, Norman, Oklahoma (Feb 2000).
11. Slavens A. and Jorgensen C., "Teaching an old sulphur recovery facility new tricks," SOGAT 2009, Abu Dhabi, UAE (Mar 2009).
12. Mosher A. and Ogg D., "SRU overpressure scenarios: waste heat exchanger failures with different sulfur sealing technologies," SOGAT 2015, Abu Dhabi (Mar 2015).
13. Clark P., Hornbaker D. and Willingham T., "Preventing corrosion in sulphur sotrage tanks," Sulphur Magazine No. 345 (Mar-Apr 2013).
14. Croom S.: "Considerations of temperature measurement in the claus thermal reaction furnace".
15. Hauer R., Juddy Z. and Sames J., "The seven deadly sins of process analyzer applications," SOGAT 2011, Abu Dhabi (Mar 2011).
16. Nasato E:, "Utility considerations for sulfur recovery units," Sulphur Conference 2014, Paris, France (Nov 2014).

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Table 1: **Frequently overlooked critical sulphur plant design details**

Item / Description	HSE risk?	Relative severity	Comments
GENERAL PLANT OPERABILITY / RELIABILITY			
Poor plant layout creates problems for liquid sulphur lines; examples include sulphur lines which are not free draining or excessive distance from pit to condensers, resulting in elevated plant and long rundowns.	Maybe	4	Difficult to correct; most likely operations will just need to find ways to cope.
Poor plant layout creates problems for overall plant hydraulics, potentially reducing plant capacity.	Not likely	4	Difficult to correct; most likely operations will just need to find ways to cope.
Inability of SRU/TGTU to achieve required turndown due to one or more of the following: controller ranges, burner design, excessive heat losses, sulphur fogging.	Not likely	3	More severe if plant is required to operate at turndown for long periods of time, in which case, continuous co-firing scheme may need to be adopted.
Mixing sour water stripper (SWS) gas and acid gas prior to preheating, leading to ammonia salt precipitation in the piping and/or burner.	Not likely	3	Can be corrected by moving mixing point to just upstream of burner and/or employing preheating but downstream plugging may have occurred.
Oxygen enrichment of an air-based SRU without properly checking WHE, refractory, and other potentially affected items to handle new operating conditions[10].	Yes	5	In the worst case, WHE failure can occur, introducing overpressure and loss of containment concerns.
No provision to bypass downstream SRU (through a start-up vent) to allow refractory heat-up and/or dry-out with excess air, after the plant has already contained sulphur.	Yes	2	Not all plants have this feature; either need to perform a very thorough sulphur sweep prior to shutdown or operate at stoichiometric conditions during fuel firing, which can introduce overheating concerns.
EQUIPMENT			
Over-design of the unit, thinking bigger (more contingency) is better, which is not usually the case for sulphur plants; an oversized unit can lead to problems achieving turndown.	Not likely	3	More severe if plant is required to operate at turndown for long periods of time; possibly mitigated by installation of multiple trains.
Insufficiently sized acid gas knockout (KO) drum that is inadequate to accommodate foaming and/or other carryover events from upstream regenerator.	Maybe	2	One major event can result in major refractory damage; larger and/or additional drums can be installed.
Improper refractory/thermal shroud system design for reaction furnace, leading to hot spots (sulphidic corrosion) and/or cold spots (acid condensation) on carbon steel [3,4].	Yes	4	If improperly designed, skin temperature measurement program may be required but is not easy to achieve; eventually, refractory will have to be repaired or replaced.
No coordination between vendors of SRU burner/reaction furnace/WHE with regard to flange alignment and installation tolerances leads to possibility for serious fit-up problems and/or overstressed nozzles; preferred fit-up assurance solutions: 1) share flange templates between vendors, 2) ship all items to one location for shop-fit up prior to transport, or 3) welded connections to be performed in field.	Maybe	4	If not properly designed and subsequent modifications are required in field, could lead to possibility for eventual loss of containment.
Inadequate number of, or poorly located, sight-ports in RF for monitoring flames, refractory and WHE tube sheet face; thermocouples (TCs) fail but visual inspection of color doesn't lie.	Maybe	3	Likely something operators will learn to cope with but could present reliability or safety risks in the long-term.
Utilising main burner for refractory dryout which may not be capable of sufficient turndown to meet temperature ramp-up schedule provided by refractory supplier; leads to excessive heat-up curve and possible refractory damage, especially a concern for large units.	Maybe	4	It is possible to hire a third-party vendor to supply a dedicated dryout burner that can be carefully controlled; however, damage to refractory may have already occurred with main burner attempt.
Improperly designed and/or fabricated WHE tubesheet with inadequate temperature protection (refractory/ ferrules) presents tube/tubesheet leak risks [1,2].	Yes	4	A tube failure is the only result that would alert operations that there is a problem; may or may not be correctable without WHE replacement.
Not considering horizontal/tangential outlet nozzles from condensers and WHE vapor outlet (WHE may condense sulphur at turndown) leads to possibility for sulphur collection in bottom of exchanger and associated tube blockage and/or corrosion concerns.	Not likely	2	Not easy to correct but not likely to cause significant problems unless nozzles are located at excessively high elevation in outlet channel; cleaning of sulphur from low points is required to prevent corrosion during a shutdown.
Use of expansion bellows in exchangers rather than flexible tubesheets; expansion joints are not required (if tubesheet is designed properly) and present leakage concerns.	Maybe	3	Something operators will have to learn to cope with unless exchanger is replaced, which is not likely.
Improper choice of reheater type, such as hot gas bypass or fired in-line burner (acid gas or fuel), especially when BTX is present, can lead to catalyst fouling and/or poisoning (note that there are appropriate times to implement various reheater types but experience is required for appropriate selection).	Maybe	4	Something operators will have to learn to cope with unless BTX poisoning of catalyst is occurring, in which case, replacement with steam heaters would be required.
Incorrect steam pressure and/or reheater design that does not allow for maximum heat input for catalyst heat soak or presulfiding (for TGTU catalyst).	Maybe	3	Operators will likely have to learn to cope, but ineffective heat soak could lead to safety concerns if sulphur cannot be removed from catalyst beds prior to shutdown.

SULPHUR PLANT DESIGN

Table 1 (continued): **Frequently overlooked critical sulphur plant design details**

Item / Description	HSE risk?	Relative severity	Comments
Operating sulphur condensers with an elevated LP steam pressure due to high steam header pressure; limited temperature approaches can lead to large condensers and possible sulphur viscosity issues.	Not likely	3	Facility LP steam header pressure may need to be reduced; if this is not possible then SRU LP steam may need to be downgraded to LLP steam quality.
Inadequate steam tracing of mist eliminators in sulphur condensers leads to possibility for plugging and high pressure drop, which decreases sulphur plant capacity and may trip the unit, if blockage is severe enough.	Not likely	3	Demister and/or heating system can be redesigned; it may be tempting to remove the mist eliminator, which is not advisable (especially in final condenser) due to risk of significant SRE decrease from sulphur vapor carryover.
Inadequate provisions for catalyst loading/unloading when designing reactor nozzles, manways and platforms leads to possibility for difficult or unsafe maintenance procedures; sufficiently sized N_2 purging system to be provided for allowing unloading of pyrophoric hydrogenation catalyst, if applicable.	Yes	4	May be very difficult to modify and operations/maintenance personnel will likely have to learn to cope; if pyrophoric hydrogenation reactor catalyst unloading provisions/ procedures are not properly designed, could lead to serious safety concerns (authors are aware of one death).
Extending castable refractory inside catalytic reactors to top of vessel rather than terminating it above the top of the catalyst bed leads to potential for improperly installed castable to fall onto catalyst bed leading to blockage or channeling.	Not likely	1	Catalyst in top of vessel can be removed upon inspection.
Inadequate cooling of sulphur in pits in warm climates can lead to high viscosity and damage or failure of pumps; also, high temperature molten sulphur can lead to poor quality solid sulphur product if granules cannot be cooled.	Not likely	3	Damage to pumps likely to occur prior to detecting a problem and possible caking of solid sulphur product in stockpile with resulting dust formation; correcting the problem requires turning off steam to sulphur pit, addition of cooler or introduction of cooling medium to steam pit coils.
Improper design of sulphur storage tanks heating and/or venting systems leads to potential for sulphur condensation, solidification, corrosion, iron sulphide deposits, fires and/or explosions.	Yes	4	If tank is improperly designed, can be very difficult to correct and fire/damage/loss of containment may occur before a problem is detected; one solution for improved heating can be external bolt-on jacketing [13].
Inadequately sized manways in refractory lined equipment limits ability to enter equipment for inspections.	Not likely	1	Likely something operators will have to learn to cope with.
Improper securing of screens on bottom of catalytic reactors lead to potential for catalyst falling into rundown lines and seal legs.	Not likely	2	Can be corrected but requires a shutdown of the unit and a full catalyst bed dump; cleaning of rundown lines and seal legs can be extremely difficult.
Poor fabrication/inspection of HP BFW exchanger welds (final condenser and sulphur cooler), leads to potential for tubesheet leakage and water/ steam into process with associated corrosion.	Maybe	3	Problem won't be detected until a leak occurs, which could result in major corrosion in the unit. Multiple tubes may be affected and therefore entire tubesheet requires inspection and repairs as necessary.
For a small SRU, multiple catalyst beds in a single reactor or multiple condensers in a single shell; improperly designed internal baffle can lead to leakage and reduced SRE.	Not likely	3	Gas bypassing will be detected by low SRE; may be difficult to get a good seal, depending on the equipment design details.
Oversized WHE on incinerator, leads to overcooling of exhaust gas (especially on turndown) and acid condensation inside stack.	Not likely	2	Damage likely to have already occurred before the problem is detected; WHE operation can be discontinued or steam temperature raised.
A TGTU start-up ejector is often a good alternative to a start-up blower, but must be steam traced, nitrogen blanketed and located at a high point to avoid corrosion, especially when not in service.	Not likely	2	Steam tracing and N_2 blanketing can be added at a later time but most likely operations will discover that the ejector is not operational when they need it, which may delay start-up.
No provision for a vacuum truck connection on sour water/amine sumps leads to pumping contaminated drains back into the unit.	Not likely	1	Vacuum truck connection can be added but contamination of process may have already occurred.
INSTRUMENTATION			
Over-thinking the shutdown logic; not everything needs to trip the SRU and the burner management has to allow reliable startups not just safe ones; too many trips actually makes the plant less safe if the operator has to bypass many of them regularly.	Yes	2	Logic can be modified but requires experience and confidence in operation.
Employment of fully manual or fully automatic burner management system (BMS) introduces safety concerns and prevents smooth transition throughout various operating modes – natural gas, co-firing, acid gas (AG) and SWS gas; a supervised manual system is required for highest safety and reliability.	Yes	3	Logic can be modified but requires experience and confidence in operation.
Poor front end measurement of air and acid gas flows; the most accurate tail gas analyzer will be of little use to the trim air valve if feed forward flow measurements to main air control valve contain significant error.	Maybe	2	Instrumentation can be changed, controls can be tuned and logic can be modified but requires experience and confidence in operation.
Flame detection for both AG and fuel gas (FG) improperly calibrated and tested in the field (in a hot and cold furnace) could result in false flame-on condition in the worst case, resulting in safety concerns, as combustible gases can be introduced without a flame.	Yes	3	If it is not realised that this can be a problem, it might not be detected unless a deflagration occurs; can be calibrated but requires experienced personnel to be present during all modes of operation.

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Table 1 (continued): **Frequently overlooked critical sulphur plant design details**

Item / Description	HSE risk?	Relative severity	Comments
No start-up, sacrificial thermocouple in reaction furnace and therefore no ability to measure temperature during heat-up and refractory dryout.	Maybe	1	Thermocouple can be inserted through pyrometer port but it only measures gas temperature, not refractory temperature.
Oversized and/or poor choice of main and trim air control valves leads to inability to achieve tight tail gas ratio control, especially if feed stream flows/compositions are changing.	Maybe	2	Valves can be changed but catalyst bed fire and/or soot deposition may have already occurred.
Lack of proper furnace temperature measurement design with regard to type, quantity, location and installation details; minimum of 2 ceramic thermocouples and 2 infrared devices (from approved suppliers) is recommended [14].	Maybe	3	Difficult to add/modify nozzles and refractory later to accommodate new or additional devices; operators will likely have to learn to cope with what they have, which could lead to safety and/or reliability concerns.
Very limited number of thermocouples in catalyst beds and/or incorrect locations within the bed leads to inability to assess catalyst performance and/or inability to detect hot spots, should they occur.	Maybe	3	Difficult to add/modify nozzles later to accommodate new or additional TCs; operators will likely have to learn to cope, which could lead to reliability concerns.
Overly long or poorly configured sample line for analyzers results in excessive lag time and inability to tightly control the process [15].	Maybe	2	Can be corrected but may take time to realise there is a problem; if analyzer relocation is required, analyser shelter location may be a problem.
No H_2S/SO_2 detector in pit vapor space for indication of potential explosive conditions and/or fires, or improperly located to give an accurate reading.	Yes	1	Analyzer can be relocated but it should be noted that there are other more effective means of preventing explosions; sulphur pits operate at a vacuum, so collecting a pit space sample can be difficult.
HEALTH, SAFETY & ENVIRONMENTAL			
Client specifications do not always explicitly dictate number and placement of H_2S monitors and leaving this up to an experienced contractor leads to the possibility of unsafe conditions in various locations throughout the facility.	Yes	5	If this is never discovered during execution, the plant will be started up and operated without adequate protection and it is likely that only a serious event will reveal that there is a problem (in one example, an entire SRU/TGTU facility was equipped with only a single H_2S monitor!)
Routing pit vent vapors to the reaction furnace without proper safety measures in place, including steam-jacketed plug valves in series; if flow is lost, higher pressure reaction furnace gases will flow backward into the un-lined piping, leading to loss of containment and H_2S release.	Yes	5	Can be modified but facilities operating without such safeguards may not realise the risk and an incident may occur before the problem is known/corrected.
Use of orifice plate rather than venturi flowmeter in combustion air line to reaction furnace burner; orifice plate incorrectly detects reverse flow as forward flow and may not trip the plant, leading to acid gas release to atmosphere through blower intake, which should be elevated but often is located at grade.	Yes	5	Can be changed but facilities operating without such safeguards may not realise the risk and an incident may occur before the problem is known/corrected.
Incorrect location of air intake and outlet on sulphur pit, leads to inadequate sweep and possible explosive conditions in pit vapor space.	Yes	5	Can be changed but facilities operating without such safeguards may not realise the risk and an incident may occur before the problem is known/corrected.
PIPING			
Inadequate purging of dead legs throughout SRU/TGTU leads to potential for plugging with sulphur and/or acid condensation and corrosion concerns.	Maybe	2	Can be modified but may have a significant plugging or corrosion event prior to recognising a problem.
Inadequate steam jacketing of liquid sulphur lines leads to potential for plugging with solid sulphur.	Maybe	3	Can be difficult to correct; bolt-on jacketing is a possible solution; rodding out and/or remelting solidified lines can be a challenge.
Sulphur seal-legs that are not sufficiently deep to withstand the maximum possible pressure in the unit (shutoff head of the blower); depth of sulphur seal legs is estimated in FEED, but must always be checked after air blower selection is made and shutoff head of blower is known.	Yes	4	Can replace with above ground sealing devices but may experience overpressure event before problem is recognised; if above-ground devices are used, WHE pressure relieving scenario should be checked [12].
Undersized rundown lines, which promote plugging and/or build-up of sulphur level in condensers, reducing surface area for condensing and possibly leading to liquid sulphur carryover to the TGTU in the worst case.	Maybe	3	Replace with above ground sealing devices but may experience sulphur carryover event before problem is recognised.
Inaccessible rundowns prevent visual inspection and access for rodding-out solid sulphur plugs; if look boxes are available, they are often sealed to prevent loss of containment and are therefore deemed ineffective for visual inspection.	Yes	3	The industry is moving toward replacing look boxes with fully enclosed sight ports, which allow confirmation of sulphur flow without H_2S release, and can be installed in existing rundown lines; if adequate rod-out connections are not provided, this is something operators will have to learn to cope with.

SULPHUR PLANT DESIGN

Table 1 (continued): **Frequently overlooked critical sulphur plant design details**

Item / Description	HSE risk?	Relative severity	Comments
Crosses not provided at all changes of direction in jacketed sulphur piping leads to inability to rod-out any solid sulphur blockages that may occur.	Not likely	4	Very difficult to correct and operators/maintenance personnel will likely have to learn to cope, which may lead to regular plant trips, depending on the reliability of the jacketing system.
Presence of low points and pockets in SRU piping where liquid sulphur and/or acid can accumulate leads to plugging and/or corrosion concerns.	Maybe	4	Very difficult to correct and operators/maintenance personnel will likely have to learn to cope.
In multi-train facilities, poor inter-connection of SRU trains for flexibility (i.e. no common acid gas header).	Not likely	3	Drip legs can be installed but collecting/draining liquid sulphur can be difficult; consider small above-ground sealing device.
Poorly located or no sample valve availability (location and type) impacts ability to collect plant operating data; Strahman piston-type sample valves are required for process samples and pressure profile testing – regular valves will become blocked with sulphur and also present a safety concern for H_2S release during the unblocking process.	Yes	4	Can be modified but not always easily, especially if sample connections are not accessible; plant test data will be unavailable, making it difficult to troubleshoot the unit.
Not providing static mixers for hot gas bypass reheat schemes leads to possibility for temperature stratification inside catalyst bed with potential for sulphur condensation.	Not likely	1	Static mixer can be added but may be difficult to correct catalyst operating conditions before doing so.
No access for portable O_2 analyser at WHE outlet impacts ability to assess plant performance during start-up before analysers have been commissioned.	No	1	Nice to have but not necessarily required.
Excessively long SRU tail gas line with inadequate heating; both sections of tail gas line are to be heated and N_2 purged (to TGTU and bypass to incinerator); a leaking tail gas valve can result in sulphur plugging and/or acid corrosion in bypass line to TGTU.	Maybe	2	Can be corrected with the addition of external bolt-on jacketing but corrosion and/or plugging may have already occurred and the line will be difficult to clean.
Poor quality steam traps and/or associated monitoring; one of the simplest devices in the unit can bring the entire plant down if not properly designed, installed and maintained [16].	Maybe	4	Difficult to correct if wrong type of steam traps are already installed; consider wireless, acoustic monitoring system to alert operations when maintenance is required.
UTILITIES			
Use of refinery fuel gas or other fuel with inconsistent composition can lead to catalyst bed fires or soot deposition due to inability to accurately determine air demand[16]; natural gas or other fuel with constant composition (e.g. LPG) is required.	Yes	2	Fuel source can be changed but catalyst damage and/or fires may have already occurred; additionally, burner operation with new fuel composition must be checked.
If purging reaction furnace nozzles with air, BMS does not automatically switch to N_2 on a trip, resulting in O_2 ingress and fires in unit[16].	Yes	3	Can be corrected with piping / BMS logic but fires may have already occurred.
Inadequate duration of N_2 purge on reaction furnace shutdown can result in burner damage due to radiant heat from reaction furnace refractory[16].	Maybe	3	Logic can be modified but burner damage may have already occurred; sometimes insufficient N_2 is available in the facility and another purging medium such as steam may need to be considered.
Neglecting to design reaction furnace refractory system for fuel firing requirements for heat-up leads to potential for refractory damage[16].	Maybe	4	Excess air or N_2 may need to be utilised for cooling but refractory damage may have already occurred.
Inadequately sized, improperly located or infrequently utilised continuous blowdown on SRU WHE leads to possibility for scale build-up on tubes and eventual tube failure[16].	Yes	2	Can be corrected but tube failure may occur prior to recognising that there is a problem; often times, a root cause analysis does not even identify the true cause so failures can be repeated again and again.
Excessive steam pressure in sulphur jacketing, leading to high viscosity and reduced flow[16].	Not likely	1	Steam pressure can be reduced.
Failure to preheat BFW above sulphur freezing temperature prior to utilising it as the process cooling medium in SRU final condenser and/or sulphur cooler leads to potential for sulphur plugging[16].	Maybe	3	BFW should be steam heated above sulphur freezing point prior to entering final condenser or sulphur cooler.
Nitrogen blanketing of sulphur pits and tanks leads to build-up of pyrophoric iron sulphide and potential for fire when air is eventually introduced; air is the preferred sweeping medium to avoid build-up of iron sulphide[13, 16].	Yes	3	Likely a relatively straightforward change to purge with air but fire may have already occurred.
Presence of heavy hydrocarbons in hydrogen supply to TGTU can lead to soot deposit on hydrogenation catalyst.	Not likely	4	Difficult to correct if appropriate H_2 source is not available and TGTU is eq uipped with a steam heater (rather than inline burner).

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- **Common mistakes in sour water stripping** A higher demand for sour water processing capacity and more stringent environmental legislation have led to an increased focus on the availability and reliability of sour water treating units. This article describes the SWS process and highlights common mistakes made when operating and designing these units.
- **More efficient heat recovery** Sulphuric acid technology companies are constantly making incremental improvements in heat recovery. Case studies for heat recovery in acid plants based on sulphur and metallurgical off-gases will be presented.
- **Sulphuric acid project listing** A round-up of new global sulphuric acid capacity, both sulphur burning and metallurgical acid production.
- **Iran and the Gulf** The easing of sanctions on Iran offers the chance for the increasing volumes of sulphur being recovered from the South Pars project to find a wider market.
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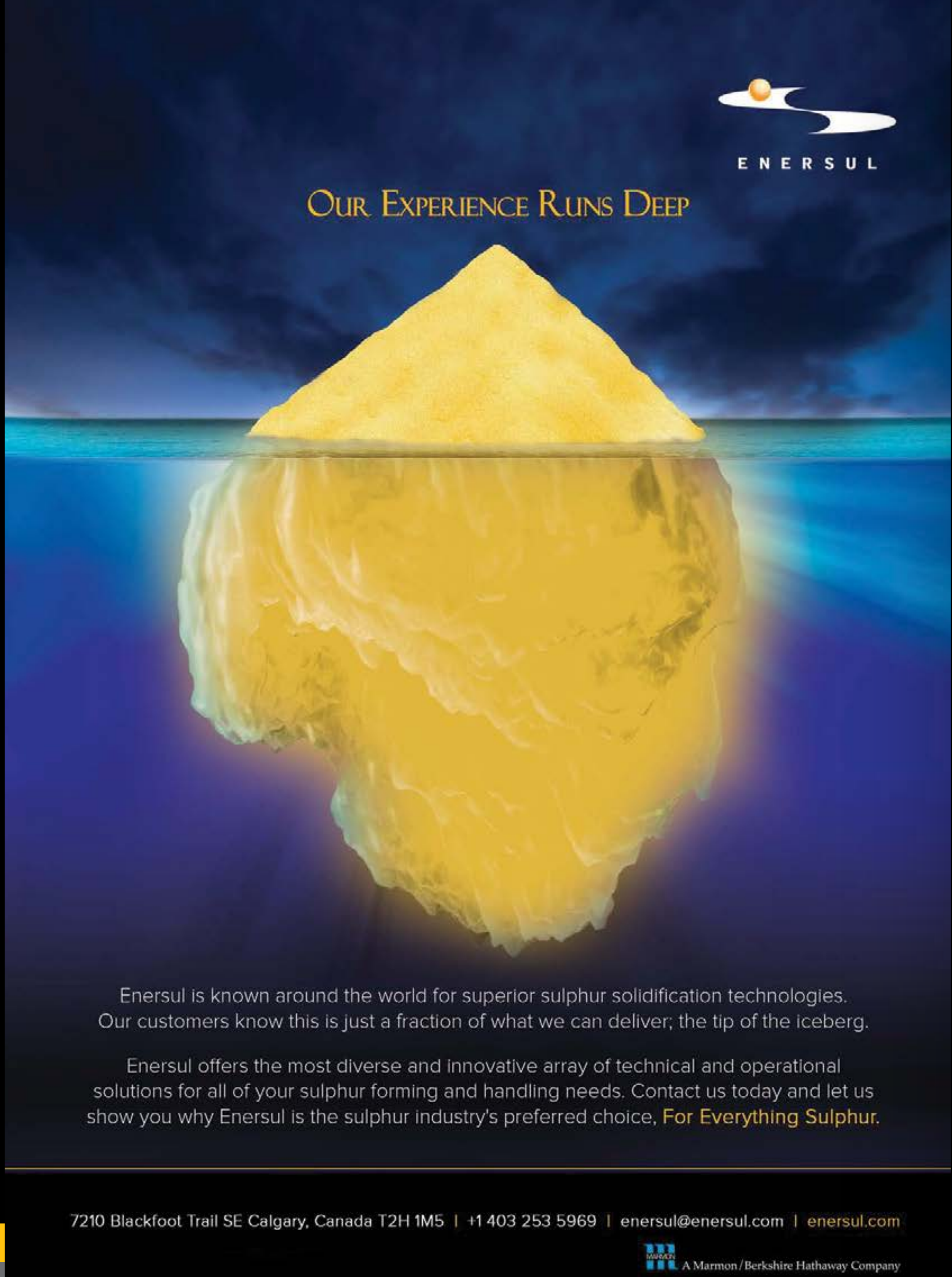

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