Number 377

July | August 2018

SULPHUR

www.sulphurmagazine.com

Welcome to our iPad version of Sulphur Issue 377

Please either swipe through or use the contents link at the bottom of the page to navigate your way around this PDF.

To use the full interactivity of this PDF on iPad we suggest that you open it within the free app iBooks.

Sulphur standards for vehicle fuels

China's sulphur import consortium

Claus tail gas treating

Sulphuric acid plant design

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52

Proven Sulphur Technologies for Capital-Efficient Solutions that Meet Clients' Environmental Requirements

Our experts at Fluor are experienced in all commercially proven sulphur technologies and develop solutions that cost-effectively satisfy our clients' environmental requirements. Our offerings include:

- Licensing COPE® oxygen enrichment technology for sulphur plant capacity expansion
- Licensing D'GAASS® liquid sulphur degassing technology for environmental benefits
- Licensing hydrogenation/amine and FLEXSORB® Claus Tail Gas Treating for 99.9+% overall sulphur recovery efficiency
- Sulphur recovery unit, tail gas treating unit and degassing plant ranges from 10-ton-per-day to 2,600-ton-per-day single trains

For more information please contact:

Thomas Chow
Vice President, Fluor Sulphur Technology

949.322.1200. tel
thomas.chow@fluor.com
www.fluor.com

FLUOR®

ADHO159818

Cover: *Refilling seen from inside fuel tank of a car.*
nexus 7/Shutterstock.com

Chinese sulphur imports

The impact of the new TGO import consortium.

Optimising sulphur recovery

Lowering the cost of tail gas treatment.

Read this issue online at: www.sulphurmagazine.com

Published by:
BCInsight

SULPHUR

www.sulphurmagazine.com

NUMBER 377 JULY | AUGUST 2018

CONTENTS

REGULARS

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52

China's flood of acid

> **A huge volume of acid may be about to appear from additional metal processing.**

Over the past 20 years, China's sulphuric acid production has grown from a 20 million t/a industry in 1997 to just under 90 million t/a in 2015, representing almost 40% of global acid production. This in turn has been mainly driven by the country's huge ramp up in phosphate fertilizer production, especially diammonium phosphate. During that time, China has moved from its traditional reliance on pyrite roasting as a source of sulphuric acid (although some capacity still stubbornly remains) via increases in smelter acid production and, particularly more recently, a huge increase in sulphur burning acid capacity. This in turn has led to China becoming the world's largest importer of sulphur, around 10-11 million t/a, or one third of all traded sulphur.

But is that due to change? The rise in China's phosphate production has been halted and overcapacity and new environmental regulations are forcing a shakeout. Acid production peaked in 2015, and over the past couple of years China's acid output has actually fallen, to around 87 million t/a in 2017, according to government statistics. Forecasts for 2018 are for a further 1.7% decline to 86.4 million tonnes.

However, while sulphur burning acid capacity may be on the wane, a huge volume of acid may be about to appear from additional metal processing. As we note in this issue's Sulphuric Acid News, new copper smelters due to come on-stream this year include Chalco's new 200,000 t/a smelter in Ningde, with a second stream of similar size scheduled for next year. Henan-based Lingbao City Jincheng will begin trial production at a new 100,000 t/a smelter in 3Q 2018, with commercial operations beginning in 1Q 2019. Tongling Nonferrous Metals Group has a new 200,000 t/a smelter at scheduled for 2H 2018. Next year should see the appearance of Yunnan Copper's 200,000 t/a Chifeng smelter in Inner Mongolia, rising to a net 270,000 t/a when a second stream starts up and an older smelter shuts down. Zhongyuan Gold will expand by 150,000 t/a, Yuguang Gold & Lead by 100,000 t/a, and Qinghai Western Mining by 100,000 t/a. Shandong Humon Smelting is increasing refined capacity by 170,000 t/a; and Guangxi Southern Copper by 300,000 t/a, with trial operation set to start either in 4Q 2018 or in 2019. Overall this could see 1 million t/a of new copper production and 3 million t/a of additional acid production over the next year or so.

Looking further down the timeline, Integer Research has identified 15-20 million t/a of potential new acid production from Chinese smelter capacity over the coming years. While the copper market may not be strong enough to bear all of this new smelter capacity, if even half of this capacity is realised or becomes operational (operating rates may fall – they have already dropped to 85%), then the likelihood is that China will suddenly be awash with a flood of cheap acid that smelters are trying to dispose of. Some of this may be exported – Chinese exports of acid already totalled 140,000 tonnes in 1Q 2018. However, probably most of it cannot be exported, and instead it may displace sulphur burning acid capacity domestically. This has the potential to reduce China's demand for and hence imports of sulphur to the tune of 3 or more million tonnes per year, in addition to increases in domestic sulphur production from refineries and sour gas processing which will also displace imports, and possibly a reduction in demand from rationalisation in phosphate capacity. In a few years' time, China may no longer be the world's largest sulphur importer, and it looks as though China's new flood of smelter acid may end up becoming extremely disruptive to sulphur markets.

Richard Hands, Editor

Price trends

MARKET INSIGHT

Oliver Hatfield, Director, Fertilizer Research Team, Integer Research (in partnership with ICIS) assesses price trends and the market outlook for sulphur.

SULPHUR

As we approach the end of the first half of 2018 and look back at sulphur price movements in isolation we can see a period of relative stability. The monthly average price of sulphur delivered to China between January and May 2018 fluctuated within a relatively narrow range of $135-150 per tonne, although weekly prices have occasionally broken out of that range. While this is substantially lower than the $200+ per tonne level recorded briefly at the end of 2017, prices in 2018 have been significantly higher than for the rest of the period going back to 1H 2015. However, the price picture alone masks considerable underlying uncertainty during this period. Throughout this period, market watchers and participants have been kept guessing about levels of demand from the big importers like China and Morocco, while disruption has affected major supply sources like Russia, and the perennial guessing game of new project timings and volumes has been continual.

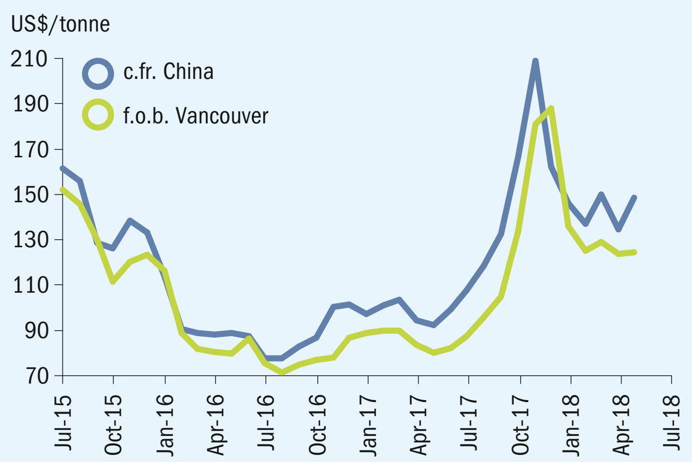
During the last few months, listed prices from the key reference points in the Middle East have fluctuated. For example, Saudi Aramco announced posted a monthly price for April 2018 at $122/t f.o.b., down by $3/t on the previous month, then bumped the May reference up to $133/t in May. Similar movements were recorded by Muntajat in Qatar and Adnoc in Abu Dhabi. Various factors supported the May increase, including Middle East refineries having limited sulphur availability due to a sweeter refinery mix, as well as seller expectations that Chinese interest in imports in June would be robust.

In China, the draw on international suppliers has been below par so far this year. The latest import data available for the first quarter 2018 shows that China imported 2.6 million tonnes, compared to 3.1 million tonnes for the equivalent period in 2017 and 2016. There are mixed reports around how much sulphur China needs to supply its world leading phosphate industry. Sulphur bulls have been anticipating healthy sulphur requirements on the basis that robust Chinese phosphate exporter activity will be necessary to meet Indian phosphate import demand. However, Chinese phosphate exports are increasingly losing market share to new sources of phosphate supply from Morocco and Saudi Arabia, while Chinese domestic demand for phosphate is plateauing. So overall it looks like the bulls may be over-optimistic. China's port stock levels have continued to creep up gradually over the last few months and reached 1.5 million tonnes in June 2018, the highest level since around a year earlier, and up from a recent low of just over 1 million tonnes in September 2017. It's of interest to note that when China's port stocks last rebounded from the 1 million tonne mark at the end of 2015 to 1.4-1.6 million tonnes during the first half of 2016, it coincided with sulphur prices falling by $40-50 per tonne.

Export supplies from the FSU have been below expectations over the last few months. While the Kashagan project in Kazakhstan is in production with volumes moving to market, these have been reportedly limited to the 4-8,000 tonnes per week range. The project is not expected to reach its 1.0+ million t/a capacity until towards the end of 2018. In addition, Black Sea sulphur export volumes were disrupted in May due to the limited availability of barges, which were reported to be in demand for grains shipments. Austrofin, a key reseller of sulphur produced by Gazprom in Russia, was unable to conclude shipments with OCP of Morocco, normally an important consumer of Russian sulphur exports. Supply shortages were also reported in Europe due to a combination of a sweeter crude slate at refineries combined with disrupted supply in Germany from the Grossenkneten gas operation, and technical problems at the Taranto refinery.

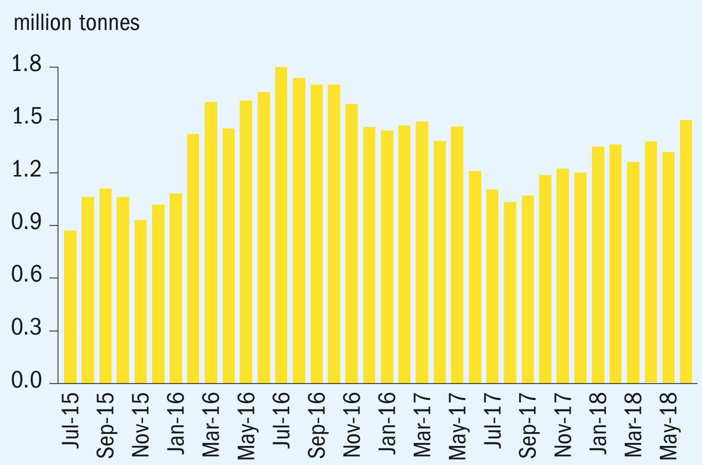
Various factors continue to add uncertainty to near term sulphur market developments. The market is likely to remain reasonably well balanced for the next few months. On the demand side, OCP recently started the last of its four finished phosphate plants under its current investment programme. At capacity, the latest unit will add around 40,000 tonnes per month of sulphur import demand to make sulphuric acid. However, the ramp up is likely to be gradual for technical and commercial reasons. For the period to April 2018, OCP imported 1.7 million tonnes of sulphur compared to 1.5 million tonnes for the

Fig. 1: **Month average spot sulphur prices, Jul 15 to Jun 18**



Source: Integer, ICIS

Fig. 2: **China sulphur port inventory, Jul 2015 to Jun 2018**



Source: Integer, ICIS

comparable period in 2017, and further growth can be expected.

On the other hand, it looks likely that availability from Russia and the Black Sea will improve over the coming months. Some anecdotal reports indicate that as much as 0.75 million tonnes of stock have accumulated inland in Russia this year due to logistical bottlenecks, some of which are likely seasonal. This position could be unwound in the second half of this year if it follows the recent pattern. According to trade statistics, Russia exported 1.0 to 1.2 million tonnes of sulphur in Q3 and Q4 2017, compared to around 0.6-0.7 million tonnes per quarter in the first half of 2017 and the first quarter of 2017.

We think the Chinese market will become increasingly influential this year and beyond. Our China office have undertaken a detailed analysis of China's sulphur and sulphuric acid market. This research shows that changes in the sulphuric acid market balance look likely to disrupt China's appetite for sulphur imports. Over the next few years we should see a raft of new smelter projects in China, adding 15-20 million t/a of by-product sulphuric acid capacity. China is already by far the world's largest smelter acid producing country, with many phosphate and other acid consumers relying on this source. It looks likely that as smelter acid production increases it will crowd out some sulphur based virgin acid volumes, which will in turn reduce sulphur demand.

SULPHURIC ACID

The bull run in the sulphuric acid market is continuing, gathering significant pace as we approach the end of the second quarter of 2018. The month average spot price of May for sulphuric acid f.o.b. Japan/South Korea reached $29 per tonne, up $1-2/t on the previous month and weekly spot values leapt by around $15 per tonne in the last weeks of June to reach $45 per tonne, the highest level since 1H 2012.

Steady demand growth has been a feature of the run up in prices which started longer than a year ago, but a key feature of the most recent spike has been disrupted supply. The closure of the Tuticorin copper smelter in India grabbed the headlines. The sulphuric acid market impact was substantial with local reports indicating that the closure resulted in domestic sulphuric acid prices doubling to $175 per tonne between May and June.

The loss of Sterlite acid production contributed to an already tight and supply disrupted Asian market. Availability in the region has already been significantly affected this year by the declaration of force majeure in January at the PASAR smelter in the Philippines due to typhoon damage. Furthermore, recent short term outages were reported at the FACT operation in India and Gresik in Indonesia. Since the fourth quarter of 2017, exports of virgin acid from China have helped with swing volume to plug the supply gap. For the first quarter of 2018, Chinese sulphuric acid exports totalled 140,000 tonnes compared to just 2,000 tonnes in Q1 2017. However, Two Lions, the main source of Chinese exports, has recently been at capacity and is reportedly sold out until July 2018.

Latest import data indicates that shipments are continuing at relatively consistent levels, suggesting that higher prices have not deterred interest from the main acid buyers. For year to date April 2018, imports to Morocco totalled 550,000 tonnes, on a par with the same period in 2017. Chile imported nearly 1 million tonnes in the YTD period to April 2018, up significantly on the 0.7 million tonnes recorded the equivalent period in 2017. However, higher prices are affecting some other smaller buying markets. For the period to May 2018, Brazilian imports totalled 144,000 tonnes; well short of prior year volume of 247,000 tonnes. It's likely that producers of SSP in Brazil are struggling to pass on higher sulphuric acid costs while prices of substitute phosphate products are strongly competitive.

In the near term, the sulphuric acid market is likely to remain tight. The lead time for availability of spot cargoes from the main export sources has consistently been pushed out over the last few quarters. The consensus in the market is that spot supply shortages will persist until 2019 at least. This sentiment is reflected in contract discussions. There are no expectations that prices are falling, the odd rollover, but the vast majority of negotiations are around agreeing the size of an increase.

Price indications

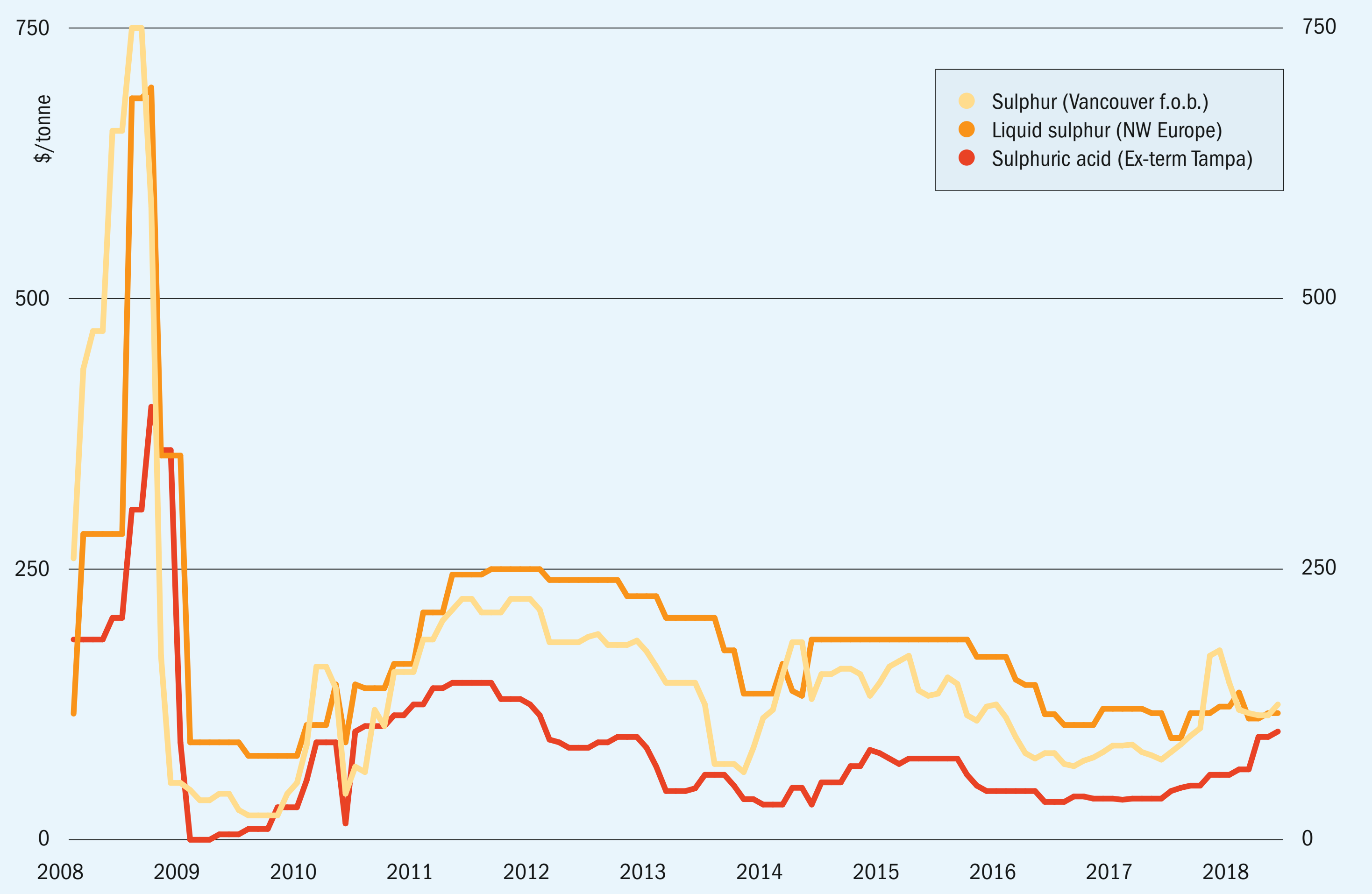
Table 1: **Recent sulphur prices, major markets**

Cash equivalent	January	February	March	April	May
Sulphur, bulk ($/t)					
Vancouver f.o.b. spot	120	117	115	115	125
Adnoc monthly contract	140	140	140	127	125
China c.fr. spot	135	135	135	135	152
Liquid sulphur ($/t)					
Tampa f.o.b. contract	116	116	116	113	113
NW Europe c.fr.	136	112	112	117	117
Sulphuric acid ($/t)					
US Gulf spot	65	65	95	95	100

Source: various

Market outlook

Historical price trends $/tonne



Source: BCInsight

SULPHUR

- The market is likely to remain reasonably well balanced for the next few months.
- OCP recently started the last of its four finished phosphate plants under its current investment programme. At capacity, the latest unit will add around 40,000 tonnes per month of sulphur import demand to make sulphuric acid. However, the ramp up is likely to be gradual for technical and commercial reasons. For the period to April 2018, OCP imported 1.7 million tonnes of sulphur compared to 1.5 million tonnes for the comparable period in 2017, and further growth can be expected.
- Availability from Russia and the Black Sea will improve over the coming months. According to trade statistics, Russia exported 1.0 to 1.2 million tonnes of sulphur in Q3 and Q4 2017, compared to around 0.6-0.7 million tonnes per quarter in the first half of 2017 and the first quarter of 2017.
- Changes in the sulphuric acid market balance look likely to disrupt China's appetite for sulphur imports. Over the next few years we should see a raft of new smelter projects in China, adding 15-20 million t/a of by-product sulphuric acid capacity. As smelter acid production increases it will crowd out some sulphur-based acid volumes, which will in turn reduce sulphur demand.

SULPHURIC ACID

- Although the most likely outcome is that prices continue to rise, or less likely plateau for the rest of 2018, we highlight several factors which could arrest the inflation:
- As always, China will be influential and unpredictable. The timing of the addition of new acid production from a raft of smelter projects mentioned in the sulphur discussion will be important. Most of these projects are likely to supply acid domestically, but some are in locations where there is potential for acid exports.
- Over the last few years OCP of Morocco has become a highly influential buyer of acid: 0.9 million tonnes in 2016, 1.5 million tonnes in 2017, and potentially 2 million tonnes in 2018. With its rapid expansion of virgin acid production capacity, the company has the potential to take advantage of any arbitrage that develops between sulphur and sulphuric acid markets.
- Relatively high sulphur prices and supply shortages have likely reduced virgin acid production over the last few quarters, but if OCP can acquire sulphur tonnes at more competitive prices and produce more acid from spare capacity, it could substantially reduce sulphuric acid imports.
- In the last few months OCP completed the last of four integrated fertilizer units at the massive Jorf Lasfar phosphate hub, as part of its current investment programme, which has the capacity to produce 1.5 million t/a of sulphuric acid, equivalent to around 8% of world sulphuric acid trade.

Sulphur Industry News

UNITED ARAB EMIRATES

Adnoc and OCP to develop global fertilizer joint venture

The Abu Dhabi National Oil Company (Adnoc) and Morocco's OCP Group have agreed to explore the phased creation of a new global fertilizer joint venture, building on the companies' respective competitive advantages; namely Adnoc's world-scale sulphur production, ammonia and gas expertise, shipping and logistics network, and OCP's access to large-scale phosphate resources, fertilizer know-how and marketing network, to develop a new global fertilizers producer. The proposed partnership will comprise two fertilizer production hubs, one in the UAE and one in Morocco (incorporating both existing and new assets), giving the proposed joint venture global market reach.

This proposed project extends the partnership already established via the long-term sulphur offtake agreement announced by the two firms in December 2017. The two companies say that they will work on developing capabilities that will support this venture. Adnoc says that the agreement aligns with its previously announced plans to increase sulphur production by at least 50% from its current level of 7 million t/a, as it looks to increase sour gas production. OCP meanwhile is engaged in a large-scale development program that will enable it to capture a larger share of growing global demand for fertilizers. The first phase of this program was completed this year and has brought the Group's existing fertilizer capacity to 12 million t/a, and rock export capacity to over 18 million t/a.

Commenting on the agreement, Dr. Sultan Ahmed Al Jaber, UAE Minister of State and Adnoc Group CEO, said: "The proposed joint venture with OCP Group illustrates ADNOC's intent to maximize the value of all our resources, as we grow our downstream business, diversify our product range and increase revenues. The agreement builds on the expanded partnership model we announced last year, as we open our entire value chain to reliable, value-adding, long-term partners, who can complement our capabilities and resources, and enhance our market access. Importantly, this agreement is aligned with the directives of our leadership to further build on the existing close relationship and ties between the United Arab Emirates and Morocco, and we look forward to building on these firm foundations as we work towards potentially building a new global fertilizers champion."

Mr. Mostafa Terrab, OCP Group Chairman and CEO, said: "This collaboration between our companies brings together the world's largest phosphate reserves and the world's largest sulphur production capacity and it represents an unprecedented alliance in the industry, providing the partners with a world-class integrated asset base and complementary geographic locations. We view this new partnership as a unique opportunity, in line with our global strategy, that will contribute to our ability to serve growing demand for fertilizers worldwide."

Massive downstream expansion planned for Ruwais

The agreement comes as Adnoc, at its recent Downstream Investment Forum, unveiled plans to become a global downstream leader, as part of the company's 2030 strategy of a more profitable upstream, more valuable downstream, more sustainable and economic gas supply, and more proactive, adaptive marketing and trading. As part of this, Adnoc plans to create the world's largest integrated refining and petrochemicals complex in Ruwais, with a total investment of $45 billion over the next five years, adding more than 15,000 jobs by 2025 and contributing an additional 1% to the country's GDP per year.

Adnoc's downstream portfolio already comprises eight companies processing 10.5 scf/d of gas, and with a refining capacity of 922,000 bbl/d of condensate and crude. They produce some 40 million t/a of refined products, and a range of other products, including granulated urea, liquefied petroleum gas (LPG), naphtha, gasoline, jet fuel, gas oil and base oils, fuel oil, and other petrochemical feedstocks. Plans are well advanced to expand the complex's refining capacity by more than 65%, or 600,000 bbl/d by 2025, through the addition of a third, new refinery, creating a total capacity of 1.5 million bbl/d. The investment program will also see the Ruwais complex upgraded to increase its flexibility and integrated capabilities to produce greater volumes of higher-value petrochemicals and derivative products. It includes a plan to build one of the world's largest mixed feed crackers, trebling production capacity from 4.5 million t/a in 2016 to 14.4 million t/a by 2025, as well as a gasoline aromatics project to upgrade light and heavy naphtha streams, to increase gasoline production; a new linear alkyl benzene project; an additional polypropylene plant; and a carbon black and delayed coker to improve product recoverability and maximise value from the bottom of the barrel.

UNITED KINGDOM

No delay to sulphur rule implementation, says IMO

Kitack Lim, secretary-general of the International Maritime Organisation, says that there is "no possibility" of any delay to implementation of the new 0.5% sulphur content rule on bunker fuels from January 1st 2020. Speaking in a press interview he said that the Sub-Committee on Pollution Prevention and Response will meet in July to develop some detailed guidance on implementing the 0.5% limit, including guidelines on relevant time schedules; the impact on fuel and machinery systems resulting from new fuel blends or fuel types; verification issues and control mechanism and actions, including port state control and in-use fuel oil samples; a standard reporting format for fuel oil non-availability; and safety implications relating to the option of blending fuels.

As the deadline looms closer, so the concerns about the potential for major disruption to global shipping markets is growing. In a new analysis of the potential impact of the bunker fuel sulphur cap, IHS Markit says that the level of compliance by shippers continues to be one of the greatest uncertainties surrounding implementation. A high level of compliance would result in a high level of market disruption while weak compliance would curtail price impacts, to a degree. The IMO is continuing to try and send the strongest possible signal to the market about compliance. In April it approved a proposal to ban carriage of non-compliant bunker fuel aboard ships that have not installed exhaust gas cleaning systems, and it is likely to be formally adopted

later this year, curtailing the opportunity for ships to burn non-compliant fuel on the open seas. The insurance industry has also begun to debate whether non-compliance with the 0.5% sulphur limit should result in ships being declared 'unseaworthy'.

From the shipping industry point of view, IHS Markit estimates that about 20,000 ships account for around 80% of heavy fuel-oil bunker fuel use. While more ships have installed or ordered scrubbers, the number is still "minimal" considering the size of the global shipping fleet, according to IHS. As of May 2018, only approximately 494 vessels had installed scrubbers. Meanwhile the forecast is that refiners will experience significant price impacts as they shift production to deliver more lower-sulphur fuels to the market and, at the same time, find a market for the higher-sulphur fuels they produce. The primary challenge for refiners is the disposal of high-sulphur residual fuel. IHS forecasts that "a sizeable portion of today's fuel oil will be pushed into lower-price tiers, notably oil-fired power-generation plants. Refining capacity will exist in 2020 to produce the low-sulphur bunker fuel, but higher overall crude runs will be required." The impact on refining margins will be fleeting but extremely significant, with impacts felt most notably in 2020 and 2021. IHS expects an unprecedented light-heavy crude oil price spread during 2020-21, significantly affecting refinery feedstock costs. During these years, middle distillate prices (diesel, kerosene, jet fuel) will spike dramatically while pricing for high-sulphur fuel oil (HSFO) will plummet.

There will be big winners and some losers in the refining industry. Simple refiners of sour crude will be negatively impacted by the nearly valueless sour crude residue, while refiners of sweet crude conversion will experience moderately higher margins, but sweet crude prices will reflect the low-sulphur residue value. But high conversion refiners of sour crude are expected to have extraordinary margins. They produce the least amount of residual fuel oil and the highest amount of distillate and gasoline.

PHOTO: FLUOR

Modules departing China for the Al Zour refinery.

KUWAIT

Modules arrive for Al-Zour project

Fluor Corp says that the first modules for the Kuwait Integrated Petroleum Industries Company (KIPIC) Al-Zour refinery project have arrived in Kuwait. Fluor is working with its joint venture partners to deliver two engineering, procurement, fabrication and construction packages for key process support units, utilities and infrastructure for the project. Upon completion, the new complex is expected to be one of the largest refineries in the world and produce 615,000 barrels per day.

Modules are being constructed at the COOEC-Fluor Heavy Industries Co., Ltd fabrication yard in Zhuhai, China. The first 14 of the 188 modules were loaded onto a shipping barge and sailed in May to Kuwait. The departure of the modules was marked by a ceremony officiated by Hatem Al-Awadhi, KIPIC's deputy chief executive officer and Jim Brittain, group president of Fluor's Energy & Chemicals business, and was attended by executive members of the project team.

"Fluor is proud to be part of KIPIC's prestigious and strategically important Al-Zour project," said Brittain. "This milestone was achieved through the collaboration and commitment of our craft professionals at the newly expanded Zhuhai fabrication yard where more than 6,500 craft workers are safely fabricating steel and pipe and assembling modules for the project."

The Fluor-led joint venture, known as FDH JV, includes Daewoo Engineering and Construction and Hyundai Heavy Industries.

"Fluor and our joint venture partners are working closely with KIPIC to implement Fluor's integrated engineering, procurement, fabrication and construction solutions across every phase of the project to enable the safe and efficient construction, commissioning and start-up of this new refinery," said Al Collins, president of Fluor's Energy & Chemicals business in Europe, Africa and Middle East.

OMAN

Work begins on new refinery

Duqm Refinery & Petrochemical Industries Co., a joint venture between state-owned Oman Oil Co. and Kuwait Petroleum, has issued contractors with formal notice to proceed with work on previously awarded contracts for the engineering, procurement, and construction of its 230,000 bbl/d refinery and petrochemical complex at the Duqm Special Economic Zone in Oman. Work on the project is scheduled to be completed in three and a half years, at the end of 2021. Initial work will be on detailed engineering design work. The $5.75 billion EPC contract is broken into three packages, with the largest, covering the main process units at the refinery, being handled by Tecnicas Reunidas SA and Daewoo Engineering & Construction Co. Ltd.

JAMAICA

Refinery upgrade begins

With an eye to providing low sulphur bunker fuel for the International Maritime Organisation (IMO) January 1st 2020 deadline, Petroleum Corporation of Jamaica and Petrojam are beginning work on a long-delayed upgrade of the country's sole, 36,000 bbl/d refinery at Kingston. The first phase, involving installation of a vacuum distillation unit, has been funded to the tune of $100 million and is under way, according to Jamaica's Science, Energy and Technology Minister, Dr Andrew Wheatley. Jamaica aims to be able to supply IMO-compliant fuels to the cruise and cargo vessels which visit the island. The refinery is 49% owned by Venezuela's state-run Petroleos de Venezuela SA (PDVSA), but the Jamaican government is in the process of trying to buy out the Venezuelan interest.

MEXICO

Pemex awards refinery contract

Petróleos Mexicanos (Pemex) has awarded the contract for rehabilitation and commissioning works to be carried out on the H-Oil Plant at the Miguel Hidalgo refinery in Tula, to a consortium of Italy's Saipem SpA and SAI Mexican SA. The $38 million proposal beat eight other bidders, according to a Pemex statement. This project will increase the production of ultra low sulphur gasoline at the refinery, and handling of crude oil for production of other fuels, such as diesel and jet fuel.

GERMANY

BASF to sub-license ExxonMobil gas treatment technology

BASF has concluded an agreement with ExxonMobil Research and Engineering Company (EMRE) on the latter's *FLEXSORB*™ technology. The agreement provides BASF with the right to sub-license the technology and supply the related solvent to third parties. *FLEXSORB* technology is well known in the industry for its selective removal of hydrogen sulphide in the presence of carbon dioxide. Exxon says that the selectivity advantage allows high H_2S removal at low solvent circulation rates, resulting in lower energy consumption compared to conventional processes. *FLEXSORB* has a commercially proven track record since 1983 with over 120 reference plants.

BASF offers solutions for the treatment of various gases such as natural gas, synthesis gas, and biogas, marketing its range of technologies, gas treatment agents, and technical services under the brand *OASE*®. "With the license from EMRE we are further strengthening our *OASE*® gas treatment portfolio, especially in the selective gas treatment area," said Dr. Andreas Northemann, head of the global gas treatment business in BASF's Intermediates division.

EGYPT

EBRD finances refinery upgrade

The European Bank for Reconstruction and Development (EBRD) is providing a $200 million loan for major investments in energy efficiency and refurbishment of the Suez Oil Processing Company (SOPC) refinery at Suez, near the entrance to the Suez Canal. The plant has a capacity of three million t/a or 68,000 bbl/d. The investments will increase the flexibility of the plant's crude intake and allow for the production of higher quality fuels and lower sulphur fuels. Part of this will include upgrades to the refinery sulphur recovery unit and additional tail gas treatment. The refinery will also undergo an extensive energy efficiency programme, leading to a direct reduction of over 295,000 t/a of carbon dioxide equivalent (CO_2e) and estimated yearly savings of 300,000 MWh of energy and 384,000 m³ of water. The Suez Refinery is operated and owned by SOPC, a fully-owned subsidiary of the Egyptian General Petroleum Corporation (EGPC), a state corporation.

Eric Rasmussen, EBRD Director, Natural Resources, said: "We are very pleased to support Egypt's strong drive towards the renewal and overhaul of its energy sector. The modernisation of the downstream segment plays an important role in this effort. The project we are signing today represents a major step forward and it also demonstrates the EBRD's commitment to support Egypt and its sustainable and successful development."

Sulphuric Acid News

INDIA

Sterlite Copper closed "permanently" after protest turns fatal

The government of Tamil Nadu says that it has ordered the "permanent" closure of the Sterlite Copper smelter at Tuticorin, following protests in May which saw police firing live rounds at protestors, killing 13 people. The smelter had been the subject of protests for over three months over environmental damage to the local area. The plant has had a history of protest from locals over its operation, leading to a court order to close the plant down in 2010 – overturned by the Supreme Court – and a sulphur dioxide leak in 2013 which led to a shutdown for several weeks and a major fine. In March 2018, the Tamil Nadu Pollution Control Board (TNPCB) rescinded the plant's license to operate over its environmental record, although studies commissioned by the Supreme Court found that the presence of sulphur and other pollutants in the ground water were within permissible limits. Nevertheless, the violence of the protests and subsequent deaths seem to have made up the state government's mind – it said that it endorsed the decision of the TNPCB and directed it to seal the unit and close the plant permanently.

Sterlite's owner, the UK-based Vedanta Group, described the decision as "unfortunate". There are four power plants in Tuticorin which burn coal with no flue gas desulphurisation, and which are suspected of emitting sulphur dioxide beyond permissible limits. Sterlite says 99% of the SO_2 emitted in the area comes from power production. Sterlite also says that it treats 99.9% of the sulphur dioxide in the smelter's off-gas to produce sulphuric acid – 600,000 t/a – avoiding the emission of SO_2.

The smelter employed 3,500 people directly, and supplied 35% of India's purified copper, around 250,000 t/a, and the closure has turned India from a net copper exporter to an importer. The closure has also led to the price of sulphuric acid in Tamil Nadu state increasing by 150%. ■

CHINA

New electronic grade acid plant

BASF SE has begun operations at a new electronic-grade sulphuric acid plant in Jiaxing, China. The 12,000 t/a plant is intended to serve the country's growing semiconductor manufacturing industry. BASF says that because of strong demand from customers, work has already begun on a second, 12,000 t/a expansion at the site to double the production capacity, and the expansion phase is expected to be operational by the end of the year. BASF predicts that demand for sulphuric acid for electronics manufacture in China will grow by around 12% per annum over the next decade, leading the company to continue to increase investment in China. Boris Jenniches, vice president for BASF's electronics materials business for Asia Pacific said that "China will take up around half of our global revenue in the electronics sector in years to come".

"The new electronic-grade sulphuric acid plant in China is another step forward in our continued growth and expansion in China's electronics market," said Jenniches. "China has already become one of the largest semiconductor markets in the world and is continuing to grow. We are excited to be a part of this momentum and will remain committed to getting closer to our customers and providing them with fast-track ramp-up of chemical solutions, reliable supply, and consistent quality."

Located at the port town of Zhapu, Zhejiang Province, southwest of Shanghai, the new plant is equipped to produce the highest quality sulphuric acid. The acid will primarily be used during the hundreds of cleaning cycles that semiconductor wafers go through in the making of microchips, which are designed in single-digit nodes measuring less than 10 nanometers across.

New smelter projects coming on-stream

Several major new copper smelters are due to come on-stream in China over the coming months after a series of previous project delays, significantly boosting the country's potential production of sulphuric acid. However, previous Chinese smelter capacity additions mean that currently the country already operates around 40% of global smelter capacity, and utilisation rates have already dropped below 85% and may fall further to 80%, meaning that the net addition to actual acid production may not be as significant, with potential closures for older, less profitable smelters.

At present, new projects due this year include Chalco's new smelter in Ningde, Fujian province, which will begin trial operations at the end of June 2018, according to the company. Refined copper capacity will be 400,000 t/a in two phases, with the first, 200,000 t/a smelter due to come online this year and the second next year, although initial production is likely to only be 100,000 t/a during operating trials. Henan-based Lingbao City Jincheng Metallurgical Co Ltd will also start trial production of a new 100,000 t/a refined copper smelter in the third quarter, with a three month period before commercial operations begin in 1Q 2019. Tongling Nonferrous Metals Group will start its new 200,000 t/a Jinchang smelter at a date yet to be declared in the second half of 2018 – a slight delay from its earlier plan for a 2Q 2018 start-up.

Other projects are likely to be slightly further out; the expansion of Yunnan Copper's Chifeng project in Inner Mongolia to 400,000 t/a from 130,000 t/a has reportedly been delayed from October 2018 to April 2019. In the first phase, Yunnan will ramp up production at a 200,000 t/a smelter to complement existing operations, and add a further 200,000 t/a of capacity in the second phase, at which point the original smelter will be closed. Henan-based Zhongyuan Gold is raising its refined copper capacity from 200,000 t/a to 350,000 t/a, and there are also projects at Yuguang Gold & Lead to increase refined capacity by 100,000 t/a, and Qinghai Western Mining, to raise refined capacity by 100,000 t/a, where trial operations started in 2Q 2018. Shandong Humon Smelting will start trial operations in 3Q 2018 on a project to increase refined capacity by 170,000 t/a; and Guangxi Southern Copper will raise refined capacity by 300,000 t/a, with trial operation set to start either in 4Q 2018 or in 2019.

Overall, around 1 million t/a of copper output is projected to start up over the remainder of 2018, with the potential addition of 3 million t/a of sulphuric acid production. However, some of these projects could continue to be delayed into 2019, and if the closure of Sterlite's smelter in India does indeed prove to be permanent, this may also help support the copper market.

CANADA

New acid plant 50% complete

Canadian mining company Teck says that the new sulphuric acid plant at its Trail Operations site in British Columbia is now half way to completion. The C$174 million facility is due to be fully operational by mid-2019. AMEC Foster Wheeler, recently purchased by the Wood Group, has been in charge of design of the plant, which is a direct copy of the No.1 acid plant, which was completed in 2014. The two new plants replace three older acid plants build in the 1960s and 70s which have now reached the end of their operational life. They process sulphur dioxide-rich off-gases from zinc smelting into sulphuric acid which is sold into the fertilizer manufacturing industry.

"The No. 2 Acid Plant is the latest major investment to further strengthen Trail's position as a world-class metallurgical facility and an important part of our business," noted Shehzad Bharmal, Vice President, North America Operations, Base Metals, Teck. "Teck, as a company, is committed to the future of Trail Operations. That is why we have worked hard over the years to strengthen the operational and environmental performance of every aspect of the smelter."

FINLAND

Outotec restructuring leads to layoffs

Outotec says that it has completed required employee cooperation negotiations concerning the restructuring of its operations in Finland. As a result, five employees will be made redundant in Espoo and 20 other staff will leave via other arrangements. Outotec had previously estimated that the restructuring could lead to the reduction of a maximum of 40 permanent jobs in Finland, mainly in support functions in Espoo. Outotec has offered work in other parts of the organization for some of the persons whose jobs will be terminated. The company says that it will support the persons to be made redundant financially and through outplacement coaching.

SWEDEN

Revamp for Boliden acid plant

Swedish mining company Boliden has contracted Outotec to design and deliver a new absorption section for the sulphuric acid plant at the Rönnskär smelter, for a price described as "more than €10 million". Boliden's Rönnskär plant is one of the world's most efficient copper smelters. The new absorption section will be able to process future gas volume from the upstream smelting process with high energy recovery. The absorber will be delivered during 2H 2019.

"We are extremely pleased that our long-term partner Boliden awarded us this order. Outotec's advanced absorption solution will safeguard the future capacity of the sulfuric acid plant and meet all of the current and planned European environmental requirements", says Kalle Härkki, head of Outotec's Metals, Energy & Water business unit.

PHOTO: BOLIDEN

Boliden's Rönnskär smelter, Sweden.

JORDAN

Brunei sells stake in JPMC to Indian firms

The Sultanate of Brunei, the largest shareholder in Jordan Phosphate Mines Company (JPMC) via its Brunei Investment Agency, has agreed to sell a 37% stake in the company to India's two largest importers and producers of fertilisers in a deal worth around $130 million. The stake is to be bought by Indian Potash Ltd and Kisan International Trading FZE, a subsidiary of the Indian Farmers Fertiliser Cooperative (Iffco). Brunei brought the stake in 2006 from Jordan when the country was seeking to attract foreign investment in an IMF-guided privatisation scheme to sell stakes in key state enterprises.

JPMC produces up to 7 million t/a of phosphate rock, and has mining rights which cover two thirds of Jordan's estimated 1.5 billion tonnes of proved phosphate reserves. PotashCorp and Mitsubishi were also reportedly interested in buying the stake. Although JPMC runs at a loss, it has been engaged in a major restructuring plan over the past two years aimed at reducing debts and cutting costs, and halved its losses in 2017 to $66 million.

SRI LANKA

Sri Lanka to produce single superphosphate

The state-owned Lanka Phosphate Company is planning to move ahead with a long-proposed project to build downstream single superphosphate (SSP) production in the country, based on phosphate mined at the Eppawala Phosphate deposit. Minister of Agriculture Mahinda Amaraweera said that the government was looking to cut the $290 million annual cost of importing finished phosphate fertilizer, as well as make savings on the further $200 million that the government spends as fertilizer subsidy. The minister said that domestic SSP production could save Sri Lanka $44 million per year as well as helping the make the country self-sufficient in its fertilizer requirements. The projected cost of the SSP plant is $56 million, and Sri Lanka is looking towards a joint venture with "an Australian fertiliser-manufacturing company". SSP is suitable for the cultivation of paddy and other crops, whereas rock phosphate can only be used for tea, rubber and coconut cultivation.

INDONESIA

Tin smelter for Indonesia

Outotec has agreed with Indonesian tin mining and processing company PT TIMAH Tbk for the design and delivery of an Outotec *Ausmelt®* top submerged lance furnace as well as associated technology and equipment for a new tin smelter, to be located at the company's existing tin smelter site at Muntok, Indonesia. Outotec has not disclosed the contract value, except to say that it is more than €10 million. The two companies entered into agreements for a technology license and process and basic engineering in 2017. The scope of Outotec's delivery has now been extended to include detailed engineering and supply of core proprietary equipment for the *Ausmelt* core technology package. TIMAH is Indonesia's largest integrated tin miner and tin processor, as well as one the world's largest refined tin exporter. The new smelter, designed to process tin concentrates for production of 45,000 t/a of crude tin, is expected to become operational in 2020.

AUSTRALIA

Offtake deal pending for Ardmore phosphate project

Centrex Metals has agreed a memorandum of understanding with Gujarat State Fertilisers & Chemicals Ltd to supply phosphate rock from its Ardmore project in Queensland. Under the terms of the MoU, Centrex will provide rock samples to GSFC's selected technology providers for the latter's new large-scale phosphoric acid plant, for their trial and acceptance. Centrex and GSFC are in the process of negotiating a binding supply agreement. Assuming a positive outcome to the testing, the companies say that they intend to finalise an off-take agreement for the supply of about 300,000 tonnes of phosphate rock from Ardmore over its proposed 10-year mine life. This represents close to 40% of Centrex's proposed output from the project.

Centrex managing director and chief executive officer Ben Hammond said; "With such a large user as GSFC showing interest on a long-term basis in our proposed premium grade ultra-low cadmium product, signing the MoU with them is a key step in expediting production from Ardmore. The potential already to sell almost 40% of our proposed output to GSFC over the mine life should give the market further confidence in what is a straight forward and simple mine development with a relatively low capital cost."

Verdant agrees supply contract for Ammaroo

Verdant Minerals has signed a non-binding memorandum of understanding with Ameropa Australia for the supply of phosphate rock concentrate. Product will come from Verdant's Ammaroo phosphate project, located 220 km southeast of Tennant Creek in Australia's Northern Territory. According to Verdant, the company will provide Ameropa, a fertilizer manufacturer, with up to 100,000 t/a of phosphate rock concentrate or other phosphate products. The main Ammaroo resource was discovered in 2010, and Verdant has been developing the project since then, with several assessments taking place in 2014. Earlier this year the company released a feasibility study for the project, reporting that Ammaroo is "technically feasible and will deliver positive economic benefits, if developed in accordance with the prescribed design criteria." The study pegs Ammaroo's initial mine life at 20 years, with output set at 1 million t/a of phosphate rock concentrate initially, increasing to 2 million t/a in the mine's sixth year. Tests indicate that the deposit will produce high-quality phosphate rock concentrate, with close to 33% P_2O_5. A final investment decision is planned for the end of Q4 2018, with construction to start in early 2019.

SERBIA

Cengiz in running to buy RTB Bor

The Serbian government is proceeding with its plans to privatise the state run copper mining and smelting enterprise RTB Bor. The move follows a restructuring of the company's debts, after a Serbian court approved a plan in 2016 to write down 90% of unsecured debt, with the remaining 10% repaid over eight years with a one year grace period. Secured debt will be converted into equity. Environmental improvements to the smelter were completed in 2015 which involved a new 1,830 t/d Outotec sulphuric acid plant. Now the government says that the company needs another €300 million ($368 million) in investment funding to increase production at the Cerovo open pit and Jama underground mines, via a strategic partnership. Among those said to be interested in taking an equity share in the company are China's Zijin Mining Group and unspecified Russian investors, and most recently Turkish conglomerate Cengiz says that it will participate in the tender for a stake, as it wishes to expand its mining business. News agency Tanjug quoted the owner of the Turkish conglomerate, Mehmet Cengiz, as saying: "mining is a specific industry and I believe that even if a country has the money to encourage its development, it is the private sector's job to do it."

ZAMBIA

Konkola Copper Mine to begin heap leaching at Mimbula

Konkola Copper Mine (KCM) has confirmed that it plans to set up a commercial heap leaching plant by 2020 at its Mimbula open pit mine in Chingola to increase copper production. The company, at its tailing leach plant, has been testing the process at a pilot test pad under the heap leach plant project to assess the availability of processing ores of varying grades at Nchanga mine and other pits such as Mimbula.

TUNISIA

Recovery in phosphate output for Tunisia

Official government figures have finally shown an improvement in Tunisia's phosphate rock production, following years of being blighted by strikes and sit-ins at the country's major phosphate producer. Monthly production figures for April and May 2018 totalled 747,000 tonnes, compared to 709,000 tonnes for the same period in 2017 and 640,000 tonnes for 2016. ■

People

Garrett Lofto, who has served as the president of J.R. Simplot agribusiness since 2009, has been named the company's new president and CEO, taking over from September 1st this year. Lofto, who has been with the company for 26 years, has led the company's agribusiness group since 2009. He replaces **Bill Whitacre**, who retired in April after 18 years with Simplot, including nine years as president and CEO. As president of Simplot agribusiness, Lofto oversaw a $2.5 billion operating division. During his tenure, the company charted significant growth in its retail arms, Simplot Grower Solutions and Simplot Partners, and opened a new state-of-the-art ammonia plant.

"I'm honoured and humbled that the board and the Simplot family have entrusted me to lead this great organization as part of the senior leadership team," Lofto said in a statement Tuesday. "The company is filled with tremendous talent and leaders, and I'm committed to ensuring they have the support they need to make the J.R. Simplot Company the best we can be."

Scott Simplot, chairman of the Simplot board of directors, praised Lofto for his vision and leadership.

"We're well-positioned for success across our organization, and the Simplot family and board of directors are confident we've got the right leader to help us achieve great things," Simplot said.

Lofto was raised on a farm in southern Manitoba, Canada, and has lived in Idaho since 2001. He earned a bachelor's degree in agriculture from the University of Manitoba and a master's degree in business administration from the University of Phoenix. He joined Simplot in 1992 as a crop adviser for the Morris, Manitoba area. He also serves on the board of directors for the Ronald McDonald House Charities of Idaho, the Fertilizer Institute, Nutrients for Life Foundation and the International Plant Nutrition Institute.

Whitacre, who steps down as president and CEO, played a key role in growing company revenues from approximately $4.5 billion to $6 billion, according to the company. Scott Simplot described Whitacre as a "highly successful and visionary leader" who helped the company reach new heights and expand its global presence. "The company, the board and the extended Simplot family thank him for his leadership and commitment," Simplot said.

Mosaic said in May that **Gregory Ebel** has become the company's new chairman of the board of directors following their annual meeting of shareholders. Ebel succeeds **Robert Lumpkins**, who had served as Mosaic's Chairman from the company's inception in 2004. Mr. Lumpkins will continue as a director to ensure a smooth transition. Mr. Ebel has served on the Board since 2012. He currently chairs the Corporate Governance and Nominating committee and also serves as a member of the Audit committee. Previously, he served as chairman, president and chief executive officer of Spectra Energy Corp and as chairman, president and chief executive officer of Spectra Energy Partners until his retirement in February 2017. He also serves as a director and chairman of Enbridge, Inc.

"Mosaic and its board of directors have benefitted immensely from Bob's dedication, leadership and insight in his role as chairman," said Mr. Ebel. "Bob was instrumental in the transactions that formed Mosaic, and his deep knowledge of the fertilizer and agriculture industries helped build Mosaic into the thriving company it is today. I'm thankful that Bob will remain on the Board, and I welcome his experience and guidance in the year ahead."

Two additional changes to the board of directors occurred at the annual meeting: **James Popowich** retired as a director, and **Oscar Bernardes** was elected to the board.

"On behalf of the entire board, I would like to extend my sincere gratitude to Jim Popowich," Mr. Ebel said. "Jim served with professional and personal passion, particularly in the areas of environmental, health and safety and sustainability. We will miss his depth of insight and technical knowledge regarding mining processes. We wish Jim all the best in his retirement."

Mr. Bernardes currently serves as managing partner, Yguaporã Consultoria e Empreendimentos Ltd., a consulting and investment firm in São Paulo, Brazil. Previously, Mr. Bernardes was a managing partner at Integra Associados – Reestruturacao Empresarial Ltda., a consulting firm specializing in financial restructuring, governance and interim management in turnaround situations, also in São Paulo; chairman of TIW do Brasil, a Canadian telecommunications company; and CEO of Bunge International, a leading global agribusiness and food company. Mr. Bernardes brings important knowledge of Brazil and its agriculture industry to Mosaic and its Board of Directors, along with expertise in international operations and risk management.

Calendar 2018/19

OCTOBER

T.B.A

Brimstone STS Advanced Sulphur Recovery Seminar, HOUSTON, Texas, USA
Contact: Mike Anderson, Brimstone STS
Tel: +1 909 597 3249
Email: mike.anderson@brimstone-sts.com
Web: www.brimstone-sts.com

14-17

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

NOVEMBER

5-8

Sulphur 2018 Conference, GOTHENBURG, Sweden
Contact: CRU Events
Tel: +44 20 7903 2167
Email: conferences@crugroup.com

28-30

European Refining Technology Conference, CANNES, France
Contact: Sofia Barros,
Senior Conference Producer & Project Manager,
World Refining Association
Tel: +44 20 7384 7944
Email: sofia.barros@wraconferences.com

FEBRUARY 2019

T.B.A

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

4-5

SulGas Gas Treating & Sulphur Recovery Conference, MUMBAI, India
Contact: Conference Communications Office,
c/o Three Ten Initiative Technologies LLP,
12-1-16 Waltair Main Road,
Visakhapatnam, Andhra Pradesh, India.
Web: www.sulgasconference.com

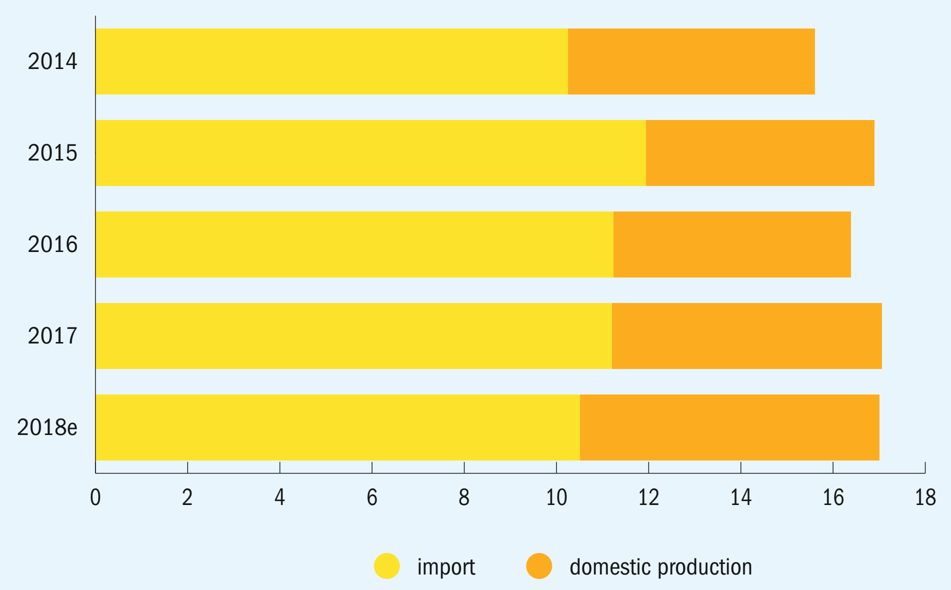
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52

PHOTO: AVIGATOR THAILAND/SHUTTERSTOCK.COM

China's sulphur import consortium

One of the most significant developments in the sulphur market in the past year has been the formation of the TGO import consortium in China. We look at the players involved and the implications for Chinese sulphur imports.

Fig. 1: **Chinese sulphur consumption, 2014-2018**



Source: TGO

China is the world's largest importer of elemental sulphur. In 2017 the country imported 11.2 million tonnes of sulphur to feed its phosphate and other industries, representing just over one third of all traded sulphur. This level of imports – about 55-60% of demand – has been relatively constant over the past few years, although it has declined slightly due to a rise in domestic sulphur production from sour gas processing. Consumption goes mainly to feed increased phosphate fertilizer production as well as industrial uses, and as Figure 1 shows, has been rising slightly over the past few years.

Chinese imports of sulphur have historically mainly been on a long-term contract basis, but since 2011 there has been a shift towards more spot buying, at least for solid sulphur. Molten sulphur, imported from Japan and Korea, as reported by CRU's Brendan Daly at the Middle East Sulphur conference in March, remains about 75% on a contract basis, and 25% on a spot basis. However, spot pricing now dominates solid sulphur imports, most of which come from the Middle East. This switch to spot pricing has in turn exposed Chinese phosphate producers to the price swings of the international sulphur market, and last year came a sign that the Chinese market may be trying to react to this via the formation of a sulphur import consortium by China's three largest phosphate producers.

The TGO consortium

There are three major fertilizer producers which make up the TGO consortium; Kailin, Yuntianhua and Wengfu. Kailin and Wengfu are based in Guizhou province, and Yuntianhua in Kunming in Yunnan province, all of them in the south-centre of China. The three companies represent China's three largest phosphate fertilizer producers, with a combined annual demand of 4.5-5.0 million t/a of sulphur.

The rationale for the decision, according to TGO, is that large market swings are harmful to both consumers and producers, and opens the market up to speculators. The Chinese sulphur market, according to TGO, is relatively distorted because there are three separate kinds of price; import prices, river and port prices, and domestic refinery prices. Import prices tend not to be connected to domestic market prices because they fluctuate more. There is also the question of exchange rate variance which adds another layer of uncertainty. TGO also say that long lead times on delivery mean that demand must be anticipated at least 40 days in advance, which is not always possible.

Consequently, the import consortium is looking to even out purchasing and gain greater control over pricing. They anticipate that their large purchasing power – 5 million t/a will make them one of the largest buyers of sulphur in the world – will give them greater negotiating power with exporters. A larger buying entity also allows for the spreading of risk – on both the supply and the demand side – and the ability to invest collectively in supply chain improvements. TGO says that it has between the three major partners the capacity to store a total of 1.9 million tonnes of sulphur. This, TGO argues, means that there can be greater continuity of purchase and sales, releasing stock pressure from the seller's side and allowing them to keep plants operating continuously. Finally, the group also hopes that its market presence might mean greater involvement and support from the Chinese government in international trade.

The participants are:

Kailin Holding Group

Founded in 1958, Kailin is China's second largest phosphate fertilizer producer, and the fourth largest phosphate producer in the world, with 5.5 million t/a of capacity. In 2017 it had revenues of $6.7 billion. It consumes 2.0 million tonnes of sulphur per year.

Yuntianhua Group

Founded in 1974, Yuntianhua is China's largest phosphate producer (and the world's third largest), with capacity of 6.5 million t/a. It had revenues of $10.5 billion in 2017, and consumed 2.5 million tonnes of sulphur.

Wengfu Group

Finally, Wengfu, started in 1988, is China's third largest fertilizer producer, with a capacity of 2.8 million t/a, and 2017 revenues of $6.4 billion. It consumes 500,000 t/a of sulphur per year.

Ports

TGO imports primarily into four ports; three in the south (Beihai, Fangcheng and Zhanjiang), and Zehnjiang/Nantong in north-central China. Zhanjiang/Nantong can handle ships of 35-50,000 dwt capacity, and has an offload capacity of 12-15,000 t/d. Zhanjiang can handle slightly larger vessels, up to 70,000 dwt, with an offload capacity of 10-15,000 t/d, and Fangcheng can also handle 70,000 dwt vessels, with a capacity of 12-17,000 t/d. Beihai is slightly smaller, taking vessels up to 45,000 dwt, with an offload capacity of 10-15,000 t/d.

Supplier relationships

TGO says that it is looking for close relationships with sulphur producers, and hopes to secure "mutually beneficial" offtake agreements for a "major portion" of its 5 million t/a of annual sulphur demand, but that it will also continue to maintain relationships with preferred traders and will also take spot "cargoes of opportunity" as and when they are available. It also says it hopes to be a "good steward" in the sulphur market, conscious of producer needs and problems, a regular presence at industry meetings and events, and interested in equity participation in joint capital expansion projects.

Middle East ties

TGO recognises that China depends in large part upon the Middle East for supplies of sulphur. Last year just under 60% of Chinese sulphur came from that region. In 2017, its first year of operation, TGO says that it purchased 3.36 million tonnes of sulphur (the first cargo purchased was at the end of March, so this does not represent a full year of activity), and 2.85 million t/a of that (85%) was from the Middle East. The consortium is thus aiming to forge long-term relationships with suppliers. It has established an office in Dubai in the UAE, just up the coast from the major sulphur exporting emirate of Abu Dhabi. Speaking at the Middle East Sulphur conference in Abu Dhabi in March this year, TGO's chief executive David Wang (who is also the managing director of Kailin International Trade), also noted that the Middle East is set to see major expansion in capacity over the next few years. Saudi Arabia is ramping up production at the Wasit gas plant, and expects additional production at Jazan in 2020 and Al Fadhili by 2021, for a total of 1.9 million t/a; Kuwait is seeing 1.2 million t/a from its new refinery; Qatar expects 800,000 t/a of new production once the Barzan gas project is commissioned, although this may not be until 2019; and Iran is expecting another 550,000 t/a of additional sulphur to 2022, mainly from South Pars. Finally, the UAE is building an expansion at the Shah sour gas project which could add another 500,000 t/a of sulphur in 2022. This means an extra 5 million tonnes of sulphur will be available from the Gulf over the next few years.

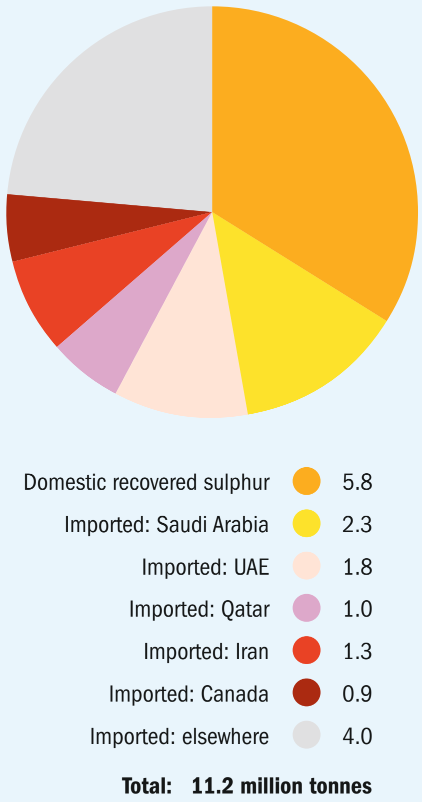
Canada

TGO has also looked to Canadian sulphur – China imported 930,000 tonnes of sulphur from Canada in 2017, as Figure 2 shows. One of TGO's first moves was to sign a supply agreement with Canadian sulphur producer Petrosul. Petrosul is a partner with Inter-Chem in the Edmonton Heartland sulphur forming project, which has a capacity of 700,000 t/a of sulphur. The project, sited 15km from Fort Saskatchewan, northeast of Edmonton, came on-stream late in 2017, and is able to take molten sulphur which would previously have been shipped by rail south into the US and form it into prills using the Devco process. The prills can then be taken to Vancouver for export abroad.

Possible merger?

Most recently, there have been rumours that there may be a merger between Wengfu and Kailin in the offing. The local provincial government of Guizhou is a major

Fig. 2: **Sources of Chinese sulphur, 2017**



Source: TGO

shareholder in both companies, and CRU reported on June 22nd that Wengfu chairman Gordon He had been nominated by the provincial government of Guizhou as the new chairman of Kailin Group. If confirmed, the merger would create the world's third largest phosphate producer after OCP and Mosaic, with a total output of 4.0 million t/a P_2O_5, pushing Yutianhua into fourth place. The Chinese phosphate sector.

China's changing phosphate sector

China's phosphate sector has grown at dizzying speed over the past decade and a half. In 2000, Chinese phosphoric acid production was around 2 million t/a (P_2O_5 basis), but by 2015 this was close to 19 million t/a, driven by a massive increase in mono-and especially di-ammonium phosphate production, changing China from a net importer to one of the largest net exporters of DAP. Integer estimates that around three quarters of the growth in Chinese demand for sulphuric acid over this period came from the phosphate industry. However, the past few years have seen a plateau in output. Domestic fertilizer application rates have peaked, and China is moving to a mandated 'zero increase' in fertilizer application from 2020. At the same time, a crackdown on pollution has led to plants being forced to relocate or even shut down. A new Environmental Protection Tax has also increased production costs for the least efficient producers at the same time that the industry also faces considerable cost pressures from overseas competitors like Morocco and Saudi Arabia, both of which are lower cost producers and, in Saudi Arabia's case, enjoys lower shipping costs to the main import market – India.

The impact of China's DAP production on the global market has served to drag down phosphate prices, forcing some higher cost producers (generally the smaller ones) out of the market, and last year saw an attempt at market discipline by Chinese phosphate producers to limit production in order to support prices.

Domestic sulphur production

The other side of the coin to Chinese imports of sulphur is the country's domestic sulphur production. China's domestic sulphur production continue to increase, reaching 5.9 million t/a in 2017, but it is estimated that it may reach 6.5 million t/a in 2018. Domestic production is mainly (75%) in the hands of Sinopec, both from its refineries and sour gas projects (such as Puguang), with China Oil (CNOOC) having another 15% of supply. The remainder is mainly in the hands of small refiners. New supply this year is expected to come from Phase III of the CNPC/Chevron Chuandongbei sour gas project, which will add 200,000 t/a of sulphur capacity, and a new PetroChina refinery in Kunming which has added 270,000 t/a of sulphur production when producing capacity.

But as far as the phosphate industry is concerned, elemental sulphur is also only one part of the picture. What phosphate producers require is sulphuric acid, and while burning sulphur remains the primary way of producing it, China also has a very significant smelting sector which generates large volumes of involuntary acid which must be sold at whatever price the smelter can get. There is also a large industry (around 5 million t/a of production) still based on the roasting of iron pyrites to produce sulphuric acid. Metallurgical acid production in China continues to rise as new copper smelters are completed. Integer assesses that in the period 2017-2019 an extra 12 million t/a of new acid production capacity will be added via metal smelting, and so Chinese acid production is also rising at the same time that demand from phosphate producers has levelled off and even begun to fall. This may lead to some acid exports from China, and the potential closure of some pyrite-based acid production (although the latter has been more resilient than many gave it credit for), but likely it will also displace some sulphur burning acid within China, leading to reduced demand for sulphur. Coupled with the increase in domestic sulphur production, this means that Chinese imports of sulphur are likely to fall over the coming years.

Will it work?

Previously Chinese sulphur buying has been relatively fragmented and uncoordinated, with individual phosphate producers negotiating separately. The coming together of buyers representing 40% of the market is thus a major step. TGO will – in theory – have an equivalent buying power to Morocco's OCP, and only slightly less than Mosaic, and both companies have been able to secure lower sulphur prices due to their purchasing power – in Mosaic's case assisted by the New Wales sulphur melter, allowing Mosaic to buy up to 1 million t/a of solid sulphur on the open market and reduce dependency on imports of molten Canadian sulphur. OCP has come to a long-term supply arrangement with Adnoc in the UAE, now the world's largest sulphur exporter. However, the companies that make up TGO are not a single entity but more disparate, with different operations and sulphur requirements. While this may change if Wengfu and Kailin do merge, it remains to be seen if they can coordinate their buying as effectively as a single purchaser. There was considerable scepticism in the market last year when TGO was formed, and accusations that its purchasing power was actually less than the sum of its parts. Nevertheless, it is still early days so far – the consortium has only been operating for just over a year, and it is still establishing new relationships with suppliers and traders and negotiating long-term contracts. The proof of the concept will come in the next couple of years. TGO represents some of the lower cost phosphate capacity in China, and hence as there are shutdowns in the industry the company's share of China's phosphate production will increase, and likewise its share of Chinese sulphur imports.

Changing vehicle fuel standards

Sulphur content of vehicle fuels remains the main driver of refinery desulphurisation capacity, and standards continue to tighten all around the world.

Fig. 1: **Global standards on fuel sulphur levels in diesel, September 2007**

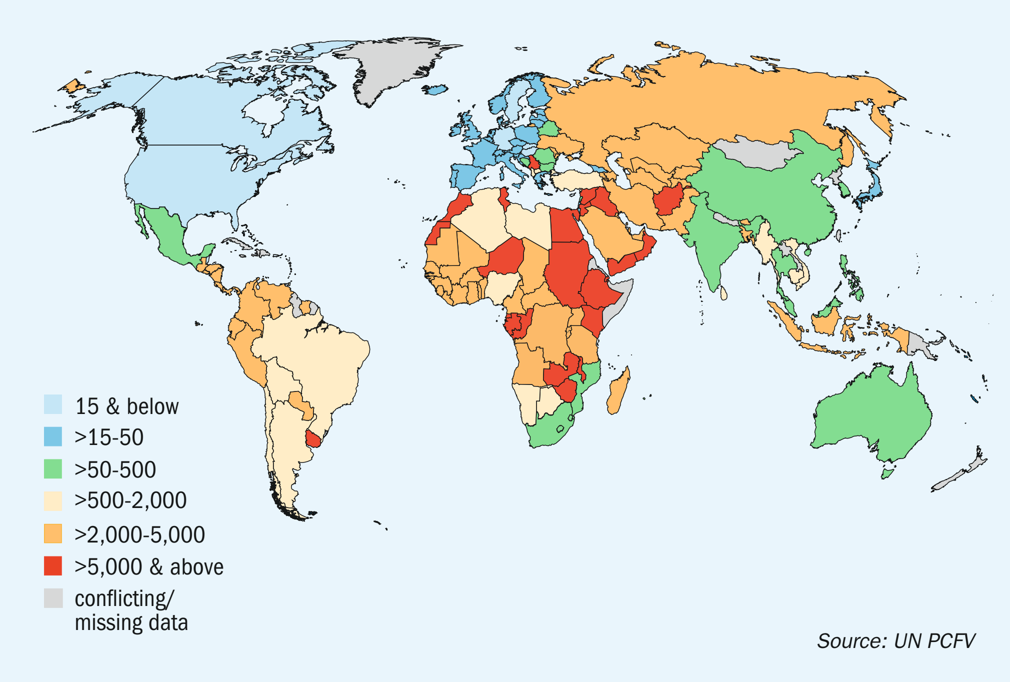
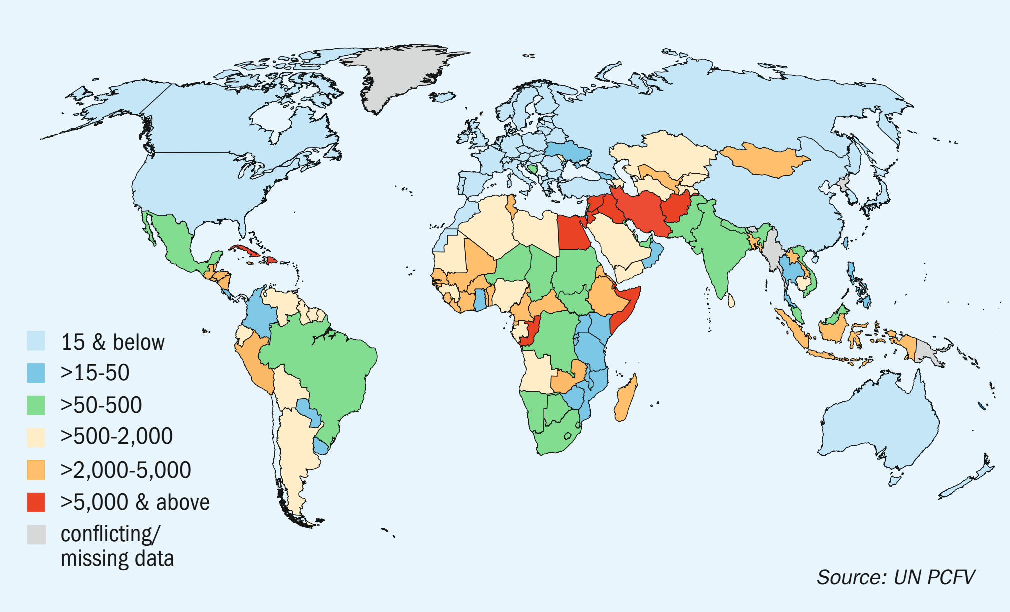


Fig. 2: **Global standards on fuel sulphur levels in diesel, March 2018**



Global regulations on sulphur in fuel continue to tighten as a result of health concerns about sulphur dioxide and its link to respiratory illness, especially in urban areas in developing and industrialising countries. Air pollution is now reckoned to be the 4th highest ranking risk for premature death globally and has been described by the UN Environmental Programme (UNEP) as the world's largest environmental health risk, responsible for 3.7 million premature deaths per year. Diesel exhaust is a significant contributor to this risk; in 2012, the World Health Organization classified diesel exhaust as a Class 1 carcinogen known to cause cancer – on par with tobacco smoke and asbestos. The global vehicle fleet is set to triple by 2050, and diesel engines dominate goods movement, construction equipment, and public transport vehicles in the global economy. Some 85% of road transportation is powered by diesel engines, which are significant sources of PM2.5 – tiny particulates which work their way into lungs and cause a variety of health problems. Diesel exhaust also accounts for up to 99% of transport black carbon emissions, which also add to global warming.

While sulphur dioxide is reckoned to contribute to many thousands of premature deaths worldwide, the focus on removing sulphur from fuels, especially diesel fuels, is also because lower levels of sulphur in fuels allow for better clean-up of other pollutants. For example, sulphur fuel levels of 500 ppm and below (so-called 'Euro II') allows the use of diesel oxidation catalysts and retrofits of older vehicles. Sulphur fuel levels of 50ppm and below ('Euro IV') allow the use of diesel particulate filters – of great importance now that particulate matter in diesel is recognised as a major pollutant in its own right. For gasoline vehicles, reducing sulphur levels to 500 ppm and below improves the performance of catalytic converter systems. This focus on SO_2 emission reduction and lower sulphur fuel levels is continuing to force continuing investment in sulphur recovery capacity at new and existing refineries worldwide, and generating millions of tonnes of additional sulphur to the market.

Diesel has been a particular concern because it can have much more sulphur on average than gasoline. The UNEP reckons that the highest sulphur level typically found in gasoline is around 1,000 ppm, but in diesel this can be as high as 10,000 ppm, coming from the partial processing of very sour crudes such as Saudi Arab Light crude (17,700 ppm) or Dubai Fateh (20,000 ppm sulphur).

Road vehicles

For diesel and gasoline-fuelled vehicles, since the World Summit on Sustainable Development in 2002 action has been coordinated via the UN Environment Programme, initially through its Partnership for Clean Fuels and Vehicles (PCFV), a collaborative venture between governments, the private sector, non-governmental organisations, and international organisations. This global partnership aims at assisting developing and transition countries in reducing urban air pollution through the promotion of clean fuels and vehicles. Their initial focus was in fact the elimination of lead in petrol, but with that largely achieved, the main activity is now the phasing down of sulphur in diesel and petrol fuels, concurrent with the adoption of cleaner vehicles and vehicle technologies. It was joined in 2012 by the Climate and Clean Air Coalition (CCAC), a voluntary partnership of governments, intergovernmental organisations, businesses, scientific institutions and civil society organisations committed to protecting the climate and improving air quality through actions to reduce short-lived climate pollutants.

Via the PCFV there has been a global commitment to reduce sulphur fuel standards to 50 ppm or lower. Progress with this can be seen in Figures 1 and 2. As of March this year, there is a sub-15 ppm diesel fuel standard (Euro-V) in virtually all of Europe and North America, Japan, South Korea and Australasia, Morocco, Turkey, Chile, Russia and, most importantly, China.

At the CCAC meeting in Marrakech earlier this year, national representatives endorsed a new global strategy which aims to introduce low-sulphur fuels and cleaner diesel vehicles. This is first global roadmap detailing how small particulate matter and black carbon emissions from the global road diesel fleet can be reduced by over 90%. It was developed following a multi-year global analysis of fuel flows and refineries. The strategy found that in spite of much progress in industrialised countries, many low and middle income countries – perhaps half of the world's nations – still use high sulphur fuels and still more lack advanced diesel vehicle standards. The strategy thus makes recommendations for specific actions in regions, countries, and cities, and presents a detailed way forward for how the world can transition to low-sulphur fuels within a decade by focusing on local markets and prioritising near-term support in key countries, aiming to reduce small particulate matter and black carbon emissions from the global on-road diesel fleet by 85% through the introduction of low-sulphur fuels and cleaner diesel vehicles. The strategy calls on all countries which have not yet done so yet to introduce action plans for the immediate introduction of low sulphur diesel fuels of 50 parts per million (ppm) or less by 2025, with 10 ppm as the final target by 2030, and for the introduction of Euro IV or equivalent vehicle emissions standards, with Euro VI standards or equivalent as the final target.

It estimates that the implementation of the strategy will prevent an estimated 100,000 premature deaths per year by 2030 globally, increasing to 500,000 premature deaths per year by 2050. It will also reduce cumulative emissions of diesel black carbon by an estimated 7.1 million metric tons through the year 2050.

Africa

A particular regional focus has been on Africa, which has had some of the laxest standards for sulphur in fuels in the world. As a result, it had become something of a 'dumping ground' for high sulphur fuels from Europe, the Middle East and other producers who were unable to sell them elsewhere. The UN CACC has therefore made Africa one of its priority areas for improvement of domestic fuel standards in recent year. This saw fruit in 2017 with a declaration by Ghana to implement low sulphur diesel standards from March 2017. Ghana was subsequently followed by Nigeria, Togo, Benin and Cote d'Ivoire after a regional high level ministerial meeting on low sulphur fuels in December 2016 in Nigeria. The ministers agreed to the import only of low sulphur diesel fuels (<50 ppm sulphur) from 1st July 2017. However, their domestic refineries were granted waivers to upgrade their facilities to produce low sulphur fuels by 2020. The countries also committed to implement cleaner vehicle policies and work with the ECOWAS Commission towards sub-regional fuel and vehicle standards harmonization by 2020. These nations were joined in November 2017 by Mozambique, Malawi and Zimbabwe. Other countries in the region which have moved to a 50 ppm diesel fuel standard include Mauritius, Kenya, Uganda, Tanzania, Rwanda and Burundi. Morocco has moved to a 10 ppm sulphur standard. The success of this can be seen in the swathe of blue covering East Africa in Figure 2.

The African Refiners Association has developed Euro-IV (50 ppm) for the production of cleaner fuels, and aims for all of its members to have moved to this by 2020 for diesel, although gasoline standards will be somewhat looser at a Euro-III level (150 ppm).

Middle East

As Figure 2 shows, the Middle East now remains one of the major holdouts for lowering domestic fuel sulphur standards. There has been a regional tendency towards 'simple' (hydroskimming), 'topping' and conversion refineries with low complexity indices. However, as much of the fuel produced is exported outside of the region, the switch towards lower fuel standards in end-user markets has nevertheless forced the region's refiners to look towards lowering sulphur content of fuels in order to continue selling into Europe in particular. A new generation of refineries have been joined by upgrades and expansions at existing plants, with additional hydrocracking, catalytic cracking and hydrotreating capacities designed to minimise low sulphur middle distillate, diesel and gasoline production. Saudi Arabia – by far the region's largest producer – has been in the vanguard of changes, as well as Kuwait. The new Jazan refinery in Saudi Arabia will produce 10 ppm sulphur fuel, and Saudi Aramco is upgrading all of its domestic refineries to produce lower-sulphur transportation fuels. Kuwait is likewise investing over $30 billion on overhauling its refining sector including the huge new Al-Zour facility, which again will produce 10 ppm fuels. Kuwait aims to become the largest producer of clean fuels in the Middle East by 2019. Other regional refineries have followed suit, including the Ruwais refinery expansion in Abu Dhabi.

North America

The US transportation fuel market is the world's largest, and moved from its 'Tier 2' (30 ppm sulphur) standard for gasoline to 'Tier 3' (10 ppm) in 2017. Refineries with a capacity of more than 75,000 tonnes per annum were required to be producing 10 ppm sulphur fuels by last year, but smaller refineries have until 2020 to meet the new specifications. This has led to considerable investment in hydrotreaters and other sulphur removal/recovery equipment in US refineries. Canada, which operates very closely with the US market, also moved to a Tier 3 standard in 2017.

China

China has moved very rapidly towards adopting a national Euro-V fuel quality standard, which became adopted nationally in 2017 for automotive diesel and January 2018 for non-automotive diesel. Chinese refiners, mainly the huge state owned conglomerates Sinopec and PetroChina, have moved quickly to build large new modern refineries and upgrade capacity at existing refineries. This has put pressure on the large independent refining sector, mainly consisting of small, simpler, so-called 'teapot' refineries. The teapots have installed some upgrading capacity and moved in general to a Euro-IV standard, but they have been forced to buy more expensive low sulphur crude from overseas to keep up with increasing fuel standards.

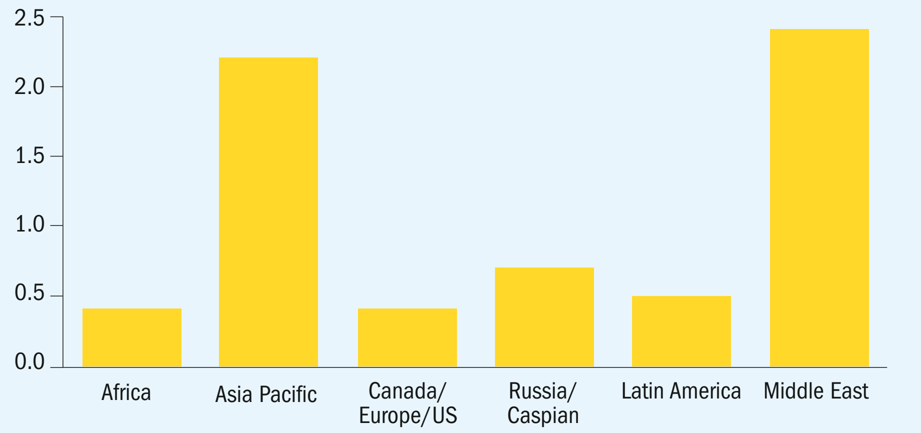
India

India has likewise been rapidly reducing its sulphur limits for fuels. Bharat stage IV (equivalent to Euro-IV) became the national fuel standard in April 2017, and the country is aiming to move to Bharat-V in 2019 and Bharat VI in 2024. It is estimated that this latter will cost the country's refining industry $11 billion in upgrading costs. Once again, however, as with China and the Middle East, India has built large, modern refineries like Jamnagar which are capable of meeting these more stringent fuel standards.

Russia

Another major exporter, Russia has also moved to produce higher grade fuels and there has been a rolling programme of refinery upgrades since 2011, with the largest refiners Rosneft and Lukoil in particular moving to Euro-V standards. As with China, however, smaller refineries have been forced to move to lower sulphur crudes in order to meet the standards, and in general Russian refiners cannot take more than 1.8% sulphur crude. With China also importing sweet crude from Russia, this has meant that Russian exports of crude have become progressively sourer, reducing margins for producers.

Fig. 3: **New refinery desulphurisation capacity, 2017-2022, million bb/d**



Source: OPEC

Maritime fuels

Of course the major change which is currently obsessing the refining industry is the upcoming move to a 0.5% limit (5,000 ppm) on sulphur content of all maritime fuels on all vessels which are not equipped with exhaust amelioration ('scrubbing') systems on January 1st 2020. This was covered in more detail in our January/February issue (*Sulphur* 374, pp20-22), but from a refining perspective the issue is that alternative fuels and scrubbing systems have had limited market penetration, and so the burden of compliance passes back to refiners, who must install expensive treatment sections before any kind of premium for low sulphur marine fuels exists. Refiners will be required to produce potentially as much as 3 million bbl/d of extra low sulphur fuel for shipping. Shell estimates that although there will be 1.5 million bbl/d of coker capacity installed by 2020, there will still be around 1.5 million bbl/d of excess HSFO and too little marine fuel oil/gas oil (MFO/MGO) by that time.

Aviation fuels

Although there have been studies conducted on the impact of moving to lower sulphur standards in aviation fuels, as yet there are no plans to introduce more stringent sulphur specifications for aviation fuels, which can often average around 300-1,000 ppm sulphur. One reason has been evidence that sulphur and SO_2 aerosols at high altitudes actually help to mitigate global warming by reflecting sunlight back into space (indeed, high altitude SO_2 release has even been suggested as a 'geoengineering' solution to mitigate climate change). However, on the other side of the equation many public health bodies, especially in Europe, are concerned about SO_2 emissions by aircraft in the vicinity of airports, and the potential for legislation in the medium term future remains quite high.

Additional sulphur

Tightening fuel regulations have been the main source of additional volumes of sulphur from refineries over the past few decades, to the point where sulphur recovered from oil is roughly equivalent to that from sour gas processing. While in Europe and North America most sulphur is already recovered, the large new refineries being built, as well as upgrades to existing facilities in Asia (especially China and India), Africa and the Middle East are going to be another major source of recovered sulphur in those markets over the next few years. Figure 3 shows new desulphurisation capacity additions to 2022, according to OPEC.

One of the largest contributors may be the new IMO bunker fuel regulations. Most (40%) of bunker fuels are currently sold in the Asia-Pacific region, with Europe and the CIS second 31%), and Africa third (16%). It is therefore refineries in these areas which are likely to have to work hardest to produce cleaner fuels. It has been estimated that up to 4 million extra tonnes of sulphur per year may come from bunker fuels.

SOGAT 2018

Pierre Crevier reports on this year's Sour Oil and Gas Advanced Technology meeting, held in Abu Dhabi from April 29th-May 3rd.

Dr Abdel Bin Subaih's keynote address.

Like a perennial flower, SOGAT came to Abu Dhabi again this year with the promise of delivering a solid technical conference, focused on delivering valuable and germane information to professionals engaged in processing sour hydrocarbons reserves. However, spring came a little late this year; SOGAT was moved from its traditional date at the end of March to minimise interference with similarly themed events related to the subjects of interest. The venue was also new; this year we gathered at the St. Regis Abu Dhabi. As an Advisory Committee member and having attended most of the last 14 SOGATs, it is encouraging to see that although the conference space on this subject has become more crowded over the last few years, SOGAT continues to attract industry participants from around the globe.

This year the organizers reported registered delegates from 17 countries. The keynote address that opened the conference proper was given on Wednesday morning May 2nd. The prior three days were taken up by a number of educational workshops that covered amine treating, sulphur recovery, sour gas process optimisation, and filtration, all presented by leading industry specialists in their respective fields.

As well as the conference and workshops, SOGAT continued to host equipment and service suppliers to the sour gas industry. This year there were 14 exhibitors, down somewhat from previous years. This may be attributable to the extreme cost cutting trend our industry has seen since the end of 2014. However, there were five new companies with stands in the exhibition area. Notably, Shell Global Solutions is the only international oil major to have maintained a continuous presence as an exhibitor.

My sense is that the overall quality of the papers and presentations at SOGAT has improved steadily over the years. This year was perhaps one of the best, with many papers focusing on this year's theme "Enhancing Cost-Effective Sour Hydrocarbon Treatment". Although some degree of commercialism is inevitable, it is certainly more acceptable when what is on offer is a truly new technical innovation for the industry. Some of the presentations highlighted in this review fall into that category. That said, the winner of the Best Paper award discussed a first principles model compared to real world measured results. This SOGAT succeeded in bringing together a good balance of operational, new (updated) technology and academic presentations.

Author: Pierre Crevier is an independent gas processing consultant based in Bahrain. His areas of expertise include sulphur recovery and forming, gas and liquid hydrocarbon treating, glycol and mol sieve dehydration, dew point control, ammonia, and ethylene manufacture.

Keynote address

The conference opening remarks were delivered by Dr Adel Bin Subaih, Manager, Undeveloped Reservoirs Project Unit at Adnoc. He underscored Adnoc's growing expertise with large scale sour and ultra-sour gas field developments. With the Shah field (around 25% H_2S) and processing facilities now operational for three years, Adnoc has demonstrated the ability to develop and operate these challenging projects. The future of the UAE's gas supply will come from sour gas, he said. Three new offshore fields, Hail, Ghasha and Dalma, are being developed in the northeast of Abu Dhabi. Front end engineering and design contracts were awarded earlier this year.

In order to maximise success in all its measures, not least of which is financial, Adnoc has invited all stakeholders to take part in the project development. This has meant inviting technology suppliers to join early in discussions on technology selection. Competitive bidding of all major aspects and phases of the project will ensure the lowest possible cost while maintaining a high standard of quality. Another key focus will be the value to be added locally by the development of these fields. 'In-country value' was a recurring theme in Dr Bin Subaih's remarks. The objective is to nurture the UAE's local service and supplier base to diversify the economy. As is always necessary when undertaking such sour projects he emphasised that health, safety and environmental considerations will be given paramount importance. Although specific figures were not mentioned regarding reserves sizes and compositions, it was indicated that these offshore fields could deliver as much as 20% of UAE gas demand in the next decade.

Closing remarks

Conference closing remarks were given by Derek Ritchie form Shell Global Solutions. Some highlights of his comments were that we can expect to continue to see volatility in oil prices with shale producers ramping up production whenever oil becomes expensive. Modularisation is an area where significant cost savings can be found in project executions. Consideration for the environment will continue to be an important factor. Diversity in the work force globally will be the key to success.

Highlights from the conference

There were a total of 22 papers presented over two days. Below is a summary of the presentations that garnered the greatest interest and discussion.

Getting the most out of your SRU performance test

Inshan Mohammed, Sulfur Recovery Engineering Inc, Canada

SRE Inc. is a company that provides SRU testing services. This involves taking process gas samples from the sulphur unit using specialised sampling procedures. From the compositional analysis, a detailed performance assessment of each piece of equipment in the unit is derived. The presentation took a thought-provoking approach; to begin with, the reasons operators don't test were listed (too expensive, don't understand the value, etc.). Thereafter, all the benefits were described in detail with reference to case studies. The cost of an SRU test is often paid for by maximising catalyst usage, Inshan said. The key to monetising the valuable data generated from this type of analysis lies in preparation for the test. The best outcomes happen when the unit engineers take ownership of the testing program.

Compact, selective H_2S removal technology

Shwetha Ramkumar, ExxonMobil Upstream Research Company, USA

The presentation described the application of ExxonMobil's *cMIST*™ technology to selective H_2S removal from sour gas. The idea behind *cMIST*™ is a compact device that produces a dispersion of fine droplets of controlled size and then separates them from the gas stream after a contact time in the range of a few seconds. Because of the mass transfer limitation for CO_2 absorption, by controlling droplet size and contact time, high selectivity can be achieved. The device is close to if not the same size as the gas piping, resulting in much smaller equipment than the alternative of a contacting tower. Data from a demonstration unit in Texas were presented. The obvious application of these devices would be offshore where weight and space are always at a premium. Commercialisation of the process by ExxonMobil appears to be on the horizon.

Separation of CO_2 and H_2S from sour gas using advanced distillation technology

Paul Higginbothan, Air Products, UK

The paper takes an "outside the box" view of removing acid gases from hydrocarbon reserves. Instead of using chemical or physical solvents to extract contaminants, it is proposed to cool and condense the gases and then separate H_2S and CO_2 by distillation. An advantage of this approach highlighted in the paper is that the acid gases are produced as a liquid which is well suited for acid gas injection.

SCOT Ultra: Staying ahead of the curve with tail gas treating

Pavan Chilukuri, Shell, Netherlands

The SCOT process originally developed by Shell in the 1970s has long been available in generic versions referred to as reductive tail gas treating. Essentially, the tail gas is passed through a reactor where all sulphur species are reduced to H_2S in the presence of excess H_2, the H_2S is then selectively absorbed in an amine contactor and recycled to the front end of the SRU. In theory and in practice this achieves very high sulphur recovery. However, when ultra-high (99.9+ percent) recovery is required as is now often the case, generic versions of the process are not up to the task. The paper discussed the two issues that ultimately limit how much recovery can be achieved and what has been developed to push the envelope further. The first relates to the operating temperature of the reduction reactor. COS hydrolysis is a reaction that does not go to completion. There is always a tiny amount of COS left over that cannot be reduced to H_2S because of an equilibrium limitation. The equilibrium is favoured (less residual COS) at lower temperature. Through their subsidiary Criterion, Shell have introduced a catalyst that can operate much cooler than conventional reducing catalysts and still achieve full conversion of non-equilibrium reactions. This means one of the factors limiting recovery, residual COS, has been significantly reduced.

The second relates to the residual H_2S in the final tail gas from the amine absorber. There are two considerations. Lower H_2S is in general favoured by lower amine temperature, clearly a limitation in the Gulf in summer. Lower H_2S can be achieved by increasing the amine circulations but aside from the obvious operating cost penalty there is also a loss in selectivity which means more CO_2 being recycled to the front end of the Claus unit. This impacts the sizing or capacity of the plant. Huntsman have introduced a new amine in their *JEFFTREAT*® line of solvents that offers lower residual H_2S partial pressure and higher selectivity for a given temperature. With these two innovations Shell assert that they have pushed reductive tail gas treating to new highs in recovery not seen until now.

CFD modelling for hazardous gas dispersion

Peter Rodgers, Khalifa University of Science and Technology, UAE

Voted the best paper at the conference, what made this paper particularly interesting was that it applied fundamental science and mathematics to address important practical problems in gas plant design and operation. Until recently, dispersion modelling of contaminants was done by what is referred to in the industry as Integrated Assessment Modelling (IAM). Deciding how tall to make a stack to disperse SO_2, what the expected concentration of H_2S from a pipe or vessel rupture at some point downstream of a prevailing wind and similar questions were determined with this methodology. IAM has the advantage that the computations required are relatively simple and therefore solvable in acceptable time frames. However, with this simplicity comes a loss of accuracy in predictions. For example IAM does not allow for actual topology of a location where a contaminant release might take place. The authors presented a new approach using computational fluid dynamic (CFD) modelling. With the ever-increasing power of computers it is possible to use first principles predict the concentration of a contaminant while taking into account the effect of terrain, buildings etc. The paper described the application of a CFD model and compared predicted and measured concentrations of a tracer compound (sulphur hexafluoride, SF_6) released to the atmosphere. Results from the CFD model matched recorded results quite closely. One important conclusion from the study is that the simpler IAM models appear to under predict contaminant concentrations. This has serious implications for plant designs and emergency response plans the author said.

During the Q&A following the presentation the point was made that, unlike much of what we do in science and engineering, where models are refined with input from experiments and operating data; in CFD modelling of contaminant dispersion it is wrong to apply fudge factors to fit measured data.

Sulphur forming projects 2018

Sulphur's annual listing of new or recently completed sulphur forming projects worldwide covers both new sour gas and refinery sulphur forming projects as well as upgrades at existing units.

System manufacturer/ supplier	Operating company	Operating site	Units	Product type	Scheduled throughput	New project/ expansion	Scheduled
CANADA							
Matrix PDM	Heartland Sulphur	Scotford	n/a	prill	2,000 t/d	new	2018
INDIA							
Enersul	Reliance Industries	Gujarat	8	granule	2,800 t/d	expansion	2018
IPCO	Bharat Petroleum	Ambalatmugal	3	pastille	800 t/d	expansion	2017
IRAQ							
Enersul	GazpromNeft	Badra	1	granule	350 t/d	new	2018
IRAN							
Zafaran	NGC	South Pars 20/21	4	granule	1,440 t/d	new	2017
Zafaran	Petropars	South Pars 19	2	granule	1,440 t/d	new	2018
Zafaran	Bushehr Petchem Co	Assaluyeh	2	granule	800 t/d	new	2019
ITALY							
IPCO	Econova	Taranto	1	pastille	192 t/d	expansion	2018
IPCO	Econova	Mililli	2	pastille	480 t/d	expansion	2018
KUWAIT							
Enersul	KNPC	Jurassic Project	1	granule	1,200 t/d	expansion	2019
Enersul	KNPC	New Refinery Project	4	granule	800 t/d	new	2019
MALAYSIA							
Enersul	RAPID	Pengerang, Johor	5	granule	2,000 t/d	new	2018
MEXICO							
IPCO	PEMEX	Coatzacoalcos	4	pastille	1,080 t/d	new	2017
NEW ZEALAND							
IPCO	Refining New Zealand	Ruakaka	2	pastille	200 t/d	new	2019
NIGERIA							
IPCO	Dangote	Lagos	3	pastille	150 t/d	new	2018
OMAN							
IPCO	SOHAR Refinery	Liwa	3	pastille	300 t/d	new	2017
QATAR							
Enersul	Qatargas	Ras Laffan	2	granule	2,400 t/d	expansion	2019
RUSSIA							
Enersul	Syzran Refinery	Samara	1	granule	350 t/d	expansion	2018
Enersul	Total	Kharyaga	1	granule	350 t/d	new	2019
IPCO	MAVEG	n.a.	5	pastille	576 t/d	new	2018
SAUDI ARABIA							
Matrix PDM	Aramco	n/a	1	prill	750 t/d	new	2017
Enersul	Aramco	Yanbu	2	prill	200 t/d	new	2018
SPAIN							
Enersul	Petroleos del Norte	Muskiz	1	granule	350 t/d	expansion	2018
TURKEY							
Enersul	Aegean Refinery	Aliaga	3	granule	1,050 t/d	new	2018
VENEZUELA							
IPCO	PDVSA	n.a.	2	pastille	264 t/d	new	2019
VIETNAM							
Enersul	Nghi Son Refinery	Nghi Son	3	granule	1,380 t/d	new	2018

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52

Philadelphia's Liberty Bell.

PHOTO: MARTIN CONYON/SHUTTERSTOCK.COM

TSI 2018

The Sulphur Institute's 2018 World Sulphur Symposium was held in Philadelphia in late April this year.

The Sulphur Institute moved back to the United States for its 2018 Sulphur World Symposium, bringing together 130 sulphur industry executives from 16 countries to discuss the latest developments in sulphur and related markets.

Energy outlook

ExxonMobil take a long view on investment in the energy market, and their outlook to 2040 was presented by William Landuyt. Global GDP continues to rise, roughly doubling to 2040, but energy demand is not rising as quickly as savings are made in consumption, with an average annual growth rate of 0.9% over the period. Even so, the next 20 years may see a 20% rise in global energy consumption. ExxonMobil as usual has a fairly cautious view of increased demand for renewables and nuclear, and predicts there will still be a rise in fossil fuel consumption, mainly natural gas, while coal use will fall, and oil demand will rise for transportation uses in spite of electrification. Global CO2 emissions from energy will peak in the 2030s. Liquid demand will be resilient, while increases in liquids supply will come mainly from natural gas liquids and tight oil production. Overall Exxon predicts a 0.7% growth in oil use year on year to 2040, 1.3% per year for natural gas, -0.1% per year for coal, and a 1.6% increase for wind, solar, biomass and nuclear (the figures for wind and solar are 5-7% year on year, but this is rising from a lower base).

China's 'Belt and Road' initiative

Undoubtedly one of the major developments of the period to 2040 is going to be China's mammoth 'Belt and Road' initiative. David Myer from the Olin Business School presented the huge strategic development plan for the development of Asia, the Middle East, and extending into Europe and Africa. There are two main components; the Silk Road Economic Belt, a series of new road, rail and pipeline links east-west across Asia with cross-connections; and the New Maritime Silk Road, a series of port developments linking to the Economic Belt through countries like Pakistan in order to facilitate trade. A large share of global sulphur and sulphuric acid production and consumption occur within this area, including Russia, China, Kazakhstan, Saudi Arabia and the UAE. The Asian Infrastructure and Investment Bank has been developed by China to finance these initiatives, founded in Beijing in 2015 with 57 member countries, and expanding by another 13 in 2017. The bank has an initial capitalisation of $100 billion.

Global economy

A global economic outlook was presented by John Urbanchuk from Delaware Valley University. Global and US economic growth is strong, he said, running at close to 2.9 million bbl/d of HSFO capaco 4% in 2018-19 and there even is an upside risk for those years. Consumer spending growth continues across all sectors and developed nations, and investment spending also has strengthened. However, as the Chinese economy has matured so growth among emerging market economies has slowed from the peak years of 2010-14. World commodity prices have stabilised over the past three years, but the global oil price is firming. The US economy is on an uptick, with 3%+ growth for 2018-19, but this will put pressure on wages and inflation – a "return to the business cycle" as John put it. Finally, he speculated that a possible renegotiation of NAFTA by the Trump administration might impact upon cross-border sulphur trade between Canada, the US and Mexico.

Caprolactam market

Mark Victory of ICIS looked at how the changing caprolactam market may affect that for sulphur. There is still overcapacity in the caprolactam market, which is likely to remain for several more years, although the gap between supply and demand is now beginning to narrow again. The US market has consolidated and the country has now become a net importer since 2017. Asia remains a net importing region, while Europe is still a net exporter, mainly to Asia. The caprolactam market remains volatile, and seems to have become disconnected from upstream benzene prices. Instead, increased nylon production has meant less merchant caprolactam availability, exacerbating temporary shortages. Chinese environmental crackdowns have reduced production there, contributing to market volatility, while changing demand from the automotive industry is leading to more nylon use as part of heat resistant plastics to reduce car weight. In the short term this will increase nylon and sulphur demand, but longer term trends depend on the uptake of electric vehicles.

IMO sulphur limits

A popular talking point this year has been the forthcoming IMO reduction in sulphur limits in bunker fuels to 0.5% in 2020. Ralph Grimmer of Stillwater Associates said that key questions still to be answered included whether there would be sufficient compliant fuel, how prevalent non-compliance would be, and whether ship owners would accept compliant blends. The uptake of scrubbing systems has been well below what was expected; perhaps only 5% instead of the anticipated 20% uptake! Consequently expectations of high sulphur fuel oil (HSFO) consumption have decreased significantly, to perhaps less than 10% of total bunker fuel consumption in 2020. From a refiner's perspective, the news is good for those with existing residual upgrading capacity, who will be able to use very sour crudes which are likely to become significantly cheaper. Conversely, there is a potential threat to simple sour crude refineries producing HSFO. Stillwater estimates that 1.8 to 2.9 million bbl/d of HSFO capacity may be displaced, with a corresponding 0.8 to 2.1 million bbl/d increase in distillate demand and increased refinery crude runs. The displaced volume of HSFO may well be greater than refinery upgrading capability to process it. In the meantime, marine fuel quality standards remain a concern.

> **There is a potential threat to simple sour crude refineries.**

As for the effect on sulphur production, Ralph predicted that spare residual processing capacity will quickly fill, while HSFO consumption by power plants will increase significantly as HSFO will become much cheaper. This would displace an estimated 5.5 million t/a of sulphur from being burned and emitted at sea into being instead captured at refineries or scrubbed at power plants, and most of it would be going to the former rather than the latter. This increase will gradually tail off as more vessels with scrubbers come on-stream.

Sulphur market

The sulphur market presentation was given by Claira Lloyd, Sulphur Editor at Argus. Middle East sulphur prices had reached a 5-year high in 2017, she said, with Chinese demand leading to a price spike. However, Chinese users did not return as expected to the market in 2018 and prices had dropped back to a more stable level since then. New demand is coming from OCP and Ma'aden, as well as Serra do Salitre in Brazil, with an extra 750,000 tonne increase expected in China, mainly from industrial consumers. On the supply side, the granular market has seen the Heartland melter in Canada approach commissioning, as well as extra supply from the Jamnagar Refinery in India, and Kashagan and Galkyniysh in central Asia, leading to a slight net market surplus in the next couple of years.

Sulphuric acid market

The sulphuric acid presentation fell to Argus' David Tonyan. He said that tight European and US supply and increased demand from Chile, Brazil and Morocco had contributed to a run-up in prices in early 2018. US supply has been impacted by the shutdown of Kennecott in late 2017, and healthy demand from mining, industrial uses and ethanol. Moroccan demand picked up due to the sulphur price spike driving increased imports of acid instead. But the outlook suggests a switch towards a longer market, he said, with Chilean imports forecast to fall as it produces more acid domestically from smelting and uses less for copper leaching. Japanese smelter acid production is expected to increase, while Europe, Boliden may expand acid output in Finland.

Phosphate market

Mosaic's Andy Jung noted that North America's phosphate sector has seen many changes over the past 20 years, seeing its global market share fall from 45% to just 17%, and its share of the merchant market drop from 55% to 10%, as well as also becoming a major import market. There has also been industry consolidation – from 20 market players to just four, and one of these, Itafos, is quite small and likely to move out of the phosphate market soon. This leaves Mosaic, Nutrien and Simplot. Of these, Mosaic is the only global phosphate producer, now having bought into Brazil via its Vale acquisition in January 2018, as well as its Saudi Arabian joint venture with Ma'aden, and a mine in Peru that feeds its Louisiana plant. In December 2017, Plant City was idled, leaving global demand ahead of supply, exacerbated by Chinese capacity rationalisation and environment-based shutdowns. On the demand side, agricultural prices are better than they have been for the past few years, and the run of lower phosphate prices encouraged faster demand growth. Global food stocks are also falling back to a level that could see increased demand again. On the phosphoric acid side, Morocco and Saudi Arabia account for almost all new capacity from 2018-22, and operating rates are heading higher, towards 80%. Wild cards in the short term include India returning to the market to cover very low DAP stocks and the impact of Chinese environmental policies.

CarbonSul

There was a lone technical presentation on Tuesday afternoon, by new technology company CarbonSul. CarbonSul aims to combine carbon dioxide with sulphur via biotechnology, using a bacterium – *acidithiobacillus thiooxidans* – to produce chemicals such as sebacic acid, which then has downstream uses in plastics manufacture. The sulphur ends up as a gypsum by-product. At present it is still very early days for this technology, which has yields of around 2%, and which the company wishes to increase to 15%. Likewise it wants to increase the energy efficiency of the process from 30% to 40%. CarbonSul says it is looking at a 5 year time horizon to genetically engineer the bacteria and optimise them.

PHOTOS: IPCO

IPCO: a new name but a familiar partner

IPCO is a new name in industrial process solutions but a business partner with whom many in the sulphur industry will already be familiar.

Left: Rotoform HS (high speed).

Previously operating as Sandvik Process Systems, best known for its Rotoform granulation process, IPCO is now an independent company within the Swedish Wallenberg group with 600 employees, more than 35 sales and service offices and annual sales in excess of €200 million. In joining the Wallenberg group, IPCO has gained the stability of being part of a business with approximately 600,000 employees and more than €140 billion in total annual sales of holdings.

IPCO will continue to develop customised solutions to enable customer success in sulphur solidification and handling plants having delivered complete end-to-end systems from receipt of molten sulphur to transport loading of solid material to hundreds of companies around the globe since 1951.

IPCO has an in-depth understanding of customer's specific processes, materials and needs. Today, IPCO translates those insights into advanced process solutions and equipment for sulphur degassing, molten truck and rail car loading, block pouring, remelting, a full range of sulphur solidification, downstream storage and reclamation, as well as bulk loading for truck, rail and ships.

In terms of solidification, IPCO provides systems to meet all throughput requirements.

The well-known Rotoform, designed for small to mid-size capacity requirements, offers unrivalled product uniformity and environmentally friendly operation. IPCO's Rotoform remains the most widely used process for the production of premium quality pastilles internationally.

Discharge of sulphur pastilles from steel belt cooler.

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52

Where higher capacity is required, the company's drum granulation systems are fully automated, once-through, sulphur granulation processes based on rotating drum technology. The revolutionary method of forming the seeds externally from the drum allows for higher operational availability and tighter control of the particle size distribution. With variable throughput rates, up to 90 t/h, this is the highest capacity granulation unit available in the market.

IPCO has supplied more than 700 sulphur forming units around the world and has offices in over 130 countries for efficient customer support.

Through its know-how, total offering and service commitment, it can anticipate and take care of customer needs long term.

IPCO strives to be the leading global industrial process partner in sulphur processing and handling, making an impact by delivering the most reliable, high-quality industrial process solutions with unmatched productivity gains and shaping the marketplace by continuously bringing new solutions and perspectives to its customers.

The Dangote Lekki Refinery project

IPCO is to supply a complete sulphur pastillation and handling package – including downstream conveying, storage and loading facilities – for the huge Dangote Lekki Refinery project currently under construction in Lagos State, Nigeria.

With a projected capacity of 650,000 barrels a day, the multi-billion dollar Dangote refinery will be the largest in Africa and is scheduled for completion by the end of 2018. Dangote Industries Limited is a privately owned, Nigerian company and one of the most diversified business conglomerates in Africa.

IPCO's responsibilities include the design, engineering, assembly, integration and service supervision of the sulphur pastillation and handling package. This covers every aspect from receipt of the molten sulphur after extraction via the Claus process, to loading systems.

Upstream equipment comprises sulphur pumps, duplex filter, IPCO ProCool system, piping and instrumentation. The ProCool is used to reduce the temperature of the molten sulphur to 125-130°C, resulting in a viscosity of between 10-15 mPa for optimum pastille quality.

The cooled sulphur will then be solidified on two IPCO Rotoform HS (High Speed) pastillation units. Operating capacity across the two units is 15 t/h and IPCO will supply the exhaust system and all necessary accessories.

Once solidified, the sulphur pastilles will be discharged onto a common collecting belt conveyor. Other downstream equipment to be supplied by IPCO includes an inclined conveyor with all related structure, and a reversible conveyor feeding two storage silos, each with a capacity of 280 tonnes.

The company is also supplying an automatic bagging system for 50 kg bags complete with pre-weighers, metal detection and automatic closing, and an automatic telescopic truck loading system with level sensors to reduce drop distance.

All loading systems are equipped with chutes designed to deposit materials with the minimum amount of dust generation.

Indian state-owned engineering company Engineers India Ltd (EIL) is providing engineering, procurement and construction management (EPCM) services for the refinery and petrochemical complex.

Steam systems in sulphuric acid plants

The 21st annual sulphuric acid workshop, held by the Florida Section of the AIChE Clearwater Convention 2018 focused this year on various aspects of engineering, specification, fabrication, operation and maintenance of heat recovery steam systems utilised in the sulphuric acid plant.

Sheraton Sand Keys Resort, Florida.

For more than 40 years now, industry engineers have gathered at Florida's idyllic Clearwater Beach for the AIChE's two-day annual convention on sulphuric acid and phosphate fertilizer technology. The convention, which is always run on a Friday and Saturday, is renowned for its relaxed atmosphere and ability to combine business with friendship, food and family. The usual eclectic of mix of international and US delegates attended the 2018 convention, which took place at the Sheraton Sand Keys Resort, on Florida's Gulf coast on 8-9June.

21st annual sulphuric acid workshop

Rick Davis of Davis & Associates and Jim Dougherty of MECS opened proceedings by organising and chairing the long-standing sulphuric acid workshop on Friday afternoon. The theme of this year's workshop was sulphuric acid plant steam systems, including fire tube boilers, waste heat boilers, superheaters, economisers and deaerators. The workshop covered the Boiler Code, process design, fabrication, quality control and water pre-treatment monitoring.

The Boiler Code

Rick Davis set the scene by explaining the objectives of the Boiler Code, as well as its limitations, in the workshop's opening presentation. The ASME Boiler & Pressure Vessel Code dates back to the early 1900s. It was part of a concerted move to improve steam engine safety prompted by the 1905 fire tube boiler explosion at the Grover shoe factory in Brockton, Massachusetts, a terrible industrial accident that left more than 50 dead and over a 100 injured.

While the first 1914 edition of the Code was a slim, single volume of just 114 pages, the latest 2011 version has 28 volumes and runs to 16,000 pages. Today, the Boiler Code is the cornerstone of operational safety, being part of the law in most US states and a standard insurance requirement. As well as making safety paramount, the Code helps set operational objectives for process temperature control and energy recovery, and also has a zero tolerance of leaks.

Two particular sections of the code were highlighted by Davis. Firstly, the rules for the construction of pressure vessels covered by Section VII, Division 1. This lists minimum requirements for materials, design, fabrication, inspection and testing of boilers. Secondly, Davis drew attention to Section VIII of the Code which deals with the operational care of power boilers – including commissioning, steam sampling and boiler chemistry.

Davis outlined the range of process specifications that engineers need to consider together with other specifications for equipment design and repair work. Process specifications include:

- determination of the thermal load for each unit;
- determination of design temperature and pressure;
- gas-side pressure drops;
- water-side pressure drops;
- process controls;
- boiler feedwater;
- blowdown;
- steam temperature;
- gas-side temperature;
- steam purity (dissolved solids);
- design for start-up.

Determining boiler equipment requirements is another challenge for the engineer. They include:

- design pressure;
- corrosion allowance;
- nozzle numbers and sizes;
- maintenance & cleaning access;
- fin density.

Davis was keen to stress that the stipulations of the Boiler Code are minimum requirements. He also pointed out that the Code has limits in terms of what it does and does not cover. The welding design of the boiler internals and gas inlets and outlets fall outside the Code, for example, as does any equipment external to the boiler and steam drum. "The Code is good but has it limits," summed up Davis. "The rest is up to you and your contractor/engineer to specify requirements."

Steam system process design

The process design of steam systems was covered in more detail in a comprehensive and thorough presentation by NORAM's **Andrés Mahecha-Botero**. He posed two 'big picture' questions: why do we need steam systems and what specifications should we use?

The basic components of a steam system are the deaerator, economiser, waste heat boiler, superheater, steam turbine and condenser. Steam system process design has four main parts:

- gas side (step 1);
- acid side (step 2);
- steam side;
- cooling water side.

As the primary design consideration, the gas side is generally the 'master' to the 'slave' steam side, suggested Mahecha-Botero. Process design also needs to answer a fundamental question in his view: what quality steam do you want to make?

Sulphuric acid plants are highly exothermic. How to capture and use surplus heat is therefore a critical consideration – by using turbo generators/power turbines to drive blowers and pumps, for example. Safety is also paramount as high temperature water and steam are both hazardous. Risks can be mitigated by:

- design review;
- hazard and operability study (HAZOP);
- relief studies;
- steam-side pressure tests;
- relief valves venting to a safe location;
- thermal insulation;
- alarms and interlocks.

It is necessary to design steam systems for a worst case scenario for temperature and pressure, advised Mahecha-Botero. This can be achieved by ensuring process design parameters incorporate a built-in margin.

Mahecha-Botero concluded his presentation with three final comments on steam system process design:

- Performance and reliability are key considerations.
- A balance needs to be struck between steam production and reliability.
- It should be possible to identify and resolve many common process problems early in the design stage.

Steam system quality control

For steam systems, the aim of quality control (QC) is to prevent defects before they occur or, if they do occur, find them during the fabrication process, explained MECS' **Ed Doe**. The most common boiler failures are due to bad welds between tubes and tubesheets. These result from:

- bad welds caused by base metal preparation;
- bad root pass welds;
- welders not using a weld procedure;
- 'bad welders' – welders making mistakes and having 'bad days';
- improper use of welder filler material;
- improper non-destructive examinations.

Choosing a competent, capable boiler fabrication company with a culture of quality is particularly important. There also needs to be evidence that the chosen fabrication company is putting QC into practice. "First impressions are often correct, so go with your gut. Go out on the shop floor – is it tidy and organised? Also check to see if QC is in place and being used," advised Doe.

Preventing defects – especially those resulting from human error – is a particular challenge given that boiler welding is a repetitive task that can involve 4,500 individual tube-to-tubesheet welds. However, defects can be prevented by having an inspection and test plan (ITP) in place during fabrication. "The best ITP is the one that's being used. Many ITPs end up being placed in the project file. It should be out on the shop floor and a dirty, dog-eared document," Doe said.

Non-destructive examination (NDE) of welds during boiler fabrication, typically by radiography, is mandatory as part of the Boiler Code. NDEs help prevent defects by "keeping welders honest", suggested Doe, as "people always do things better when they're being watched". He advised that NDE is best done by radiography of randomly-selected welds. These need to be selected after they have been made as it is important for the welder not to know which have been chosen in advance.

Fabrication

Mike McGuire of Optimus described the practicalities of boiler fabrication and the design process behind this. Optimus first began fabricating speciality boilers, economisers and fin tubes in the early 1990s. The company sold its first waste heat boilers (WHBs) and economisers for the sulphuric acid market in 1996. The company also supplies a range of superheater designs including pendant and cylindrical types. Notable references include:

- MECS waste heat boiler and MECS sulphuric acid economiser for Mosaic's New Wales complex;
- large economiser for the PCS Aurora plant;
- Morses Mill, New Jersey sulphuric acid superheater.

Boiler design initially involves the preparation of design drawings incorporating engineering data. These are then submitted for customer review, prior to the drafting of detailed fabrication drawings. Design pressure and temperature requirements are set out in the following sections of sections of the ASME Boiler Code:

- Shell-side: boiler construction rules in Section 1 (WHB) and recommended guidelines in Section VII (Economiser/Superheater)
- Tube/gas-side: pressure vessel construction rules Section VIII, Division 1

The Code also contains calculations for determining the thickness of components such as shells, tubesheets, vestibules, stand-off rings and saddles. Structural design (WHB saddles, gas nozzles, piping, foundation loads etc.) is another important part of the design process.

Deaerator and steam/condensate system monitoring

Edward Sylvester of Chemtreat ended the workshop with a lively, energetic presentation on the objectives of pre-treatment monitoring. Diligent monitoring is necessary to ensure:

- high quality water;
- pre-treatment equipment is operating at peak performance;
- immediate isolation and correction of any ingress.

As a first step, pre-treatment plants and reverse osmosis (RO)/ demineralisation plants are used to supply high-quality make-up water to the deaerator. Subsequent monitoring at every stage of the steam/condensate system also helps guarantee:

- high quality feedwater for the steam generator;
- high quality steam for the plant process turbine;
- high quality condensate.

The ASME provides guidelines on water chemistry and treatment. These set out the quality requirements for make-up water, feedwater, steam and condensate. "Steam/condensate system quality should be very good," advised Sylvester. The only allowable chemicals are neutraliser amines, volatile O_2 scavenger, and sodium and silica at parts per billion level. "On the water-side, our objective is to protect your investment," summed up Sylvester.

Optimised sulphur recovery with minimal investment

Due to ever increasing mandates to lower SO_2 emissions and reducing operating margins, refiners and gas plant operators are always looking for ways to lower the operating cost of their tail gas treatment units. New processes, catalysts and solvents have been developed to meet these objectives. In this article we report on Shell's SCOT ULTRA process, Dow's UCARSOL™ TGT series of solvents and Keyon's S-Plus technology.

Site photo of S-Plus unit (Claus+DSR), 50 t/d sulphur.

PHOTO: KEYON PROCESS

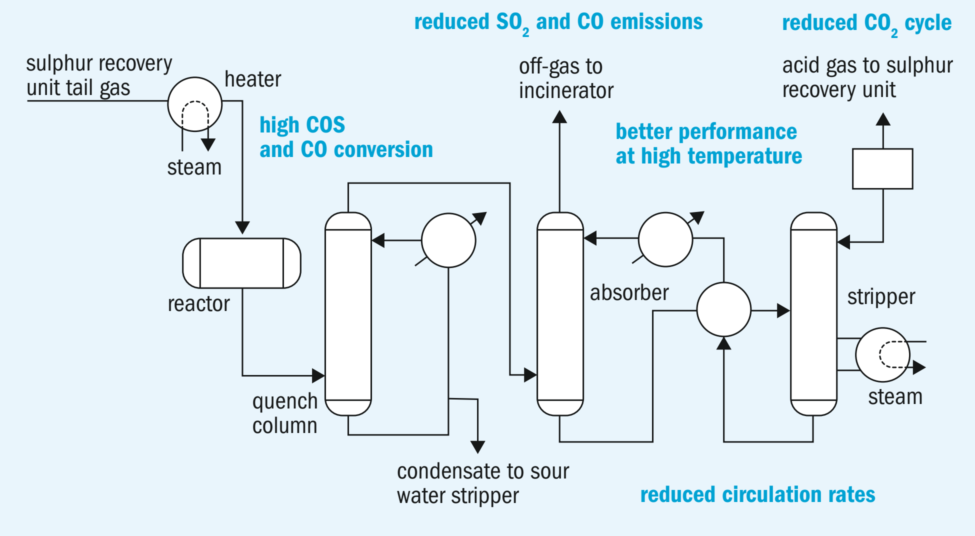
Refiners and gas plant operators are under pressure to meet increasingly stringent global SO_2 emission regulations varying from 50 to 150 mg/Nm^3 SO_2. Considerable investment in capital and operating expenditure may be required to implement the technology required to meet these standards, so choosing the right line-up is essential for minimising the impact on the bottom line of the facility. It is also essential for facilities to develop a long-term plan which accounts for any future tightening in SO_2 emission specifications.

A tail gas treater is a gas treating system where the low pressure off-gas from a sulphur production system at a refinery is further polished to remove H_2S to trace levels.

When H_2S is selectively removed from the sulphur plant tail gas, the solvent is regenerated to produce a concentrated H_2S stream. This concentrated H_2S stream is recycled to the sulphur plant for conversion to elemental sulphur. The gas that passes through the tail gas absorber is combined with other process streams and incinerated before being released to the atmosphere. Any sulphur species not captured by the tail gas treater are oxidised to SO_2. Since all emitted sulphur is converted to SO_2, government regulations typically focus on total SO_2 emissions.

The Shell Claus off gas treating (SCOT) process is the industry's most widely selected tail gas clean up technology with over 300 references worldwide. It can

Fig. 1: **SCOT ULTRA line-up and benefits (highlighted in blue)**



Source: Shell Global Solutions

achieve sulphur recovery levels of up to 99.98%, resulting in very low SO_2 emissions from sulphur recovery units. Tightening regulations and the requirement to process more complex sour gas and sour crude slates have resulted in existing tail gas treatment units becoming key constraints and operators are always looking for methods to improve the performance of their sulphur recovery units and tail gas treating units without incurring a substantial increase in capital and operating cost.

SCOT ULTRA for operational and environmental benefits

Shell Global Solutions recently developed the SCOT ULTRA process (Fig. 1), which offers a step change improvement in the performance of the well-established line of SCOT processes. The installation or conversion to the SCOT ULTRA technology can help operators meet more stringent emissions regulations, even with highly challenging and highly contaminated feeds. In most situations there is no requirement to modify equipment with the conversion. In most scenarios, the SCOT ULTRA installation can be done via only a solvent and catalyst swap, without even the requirement to install a water wash to reduce solvent losses. The new option is an improvement of an existing, well established and proven technology and as such can be considered to be fundamentally de-risked.

It features the highly selective JEFFTREAT ULTRA family of solvents, which were developed jointly between Shell and the Huntsman Corporation. This line of solvents can achieve a substantial improvement in the reduction of H_2S from the absorber in the SCOT plant as well as provide an improvement in the selectivity of the solvent for H_2S over CO_2. The JEFFTREAT ULTRA family of solvents offers several advantages over conventional MDEA in revamp applications. For example, the higher selectivity means that it can achieve deeper H_2S removal specification as well as reduce the impact of CO_2 circulation in the SCOT off gas recycled back to the Claus thermal reactor. In addition, the new JEFFTREAT ULTRA solvent is able to maintain high H_2S absorption at higher temperatures with improved CO_2 slip, thereby making this solution very applicable for warmer climates, where typically refrigeration would be required to deliver solvent performance.

The technology also features the latest Criterion Catalyst and Technologies C-834 LT-SCOT catalyst. The C-834 catalyst adds value by improving the conversion of organic sulphur compounds, which if not converted will lead to higher SO_2 emissions from the facility. The C-834 LT-SCOT catalyst has been designed to provide exceptionally high activity at low operating temperatures, compared to current industry standard. Being able to operate the tail gas treating unit (TGTU) at a low temperature allows the operators to extend the cycle length of the unit as well as reduce energy consumption by using steam reheating instead of inline burners. The crucial component of the catalyst however is its ability to provide improved hydrolysis and hydrogenation performance, resulting in increased destruction of organic sulphur compounds such as COS, which are found in higher concentrations in the tail gas from SRUs due to the processing of more contaminated acid gas streams in gas plants and refineries. In addition, the catalyst also offers a potential low pressure drop, which is a key parameter for TGTUs as most often there is not a lot of excess pressure available for these units.

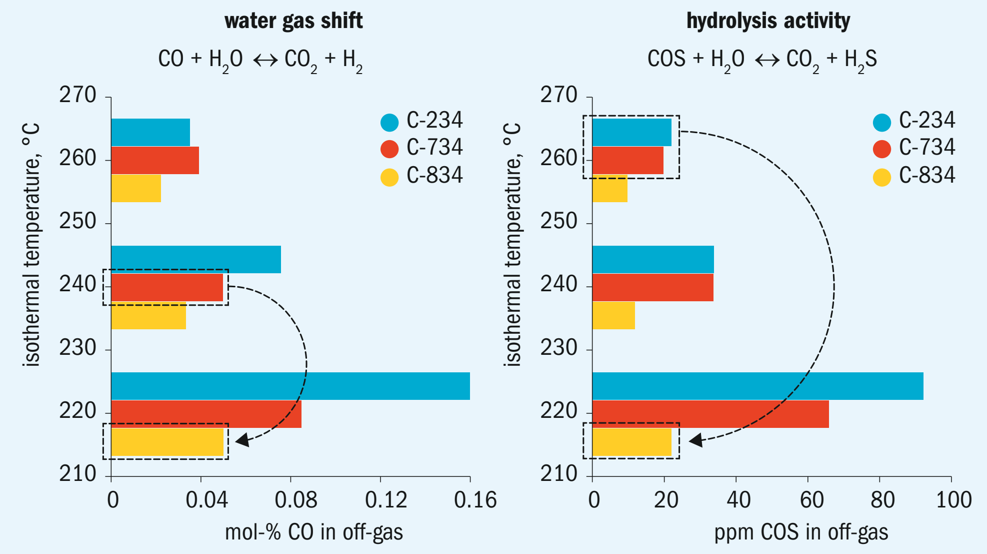
The new SCOT ULTRA process could be particularly valuable for operators tasked with meeting more stringent SO_2 emissions, without installing new technology.

Table 1: **SCOT ULTRA advantages for greenfield and brownfield sites**

Greenfield installation	Brownfield installation/revamp
Smaller equipment including the absorber height.	Easy solvent swap is possible to significantly reduce H_2S and organic sulphur species from the SCOT absorber.
Ability to meet the more stringent specification without the requirement of a chiller section.	Improve margin due to unit flexibility of processing more sour crudes or higher CO_2 containing sour gas streams.
Smaller plot space requirements.	Lower opex due to lower steam, cooling and power consumption as a result of the lower circulation of solvent compared to conventional solvents.
Lower OPEX due to lower steam, cooling and power consumption as a result of the lower circulation of solvent compared to conventional solvents.	Reduced catalyst fill costs.
Flexibility in processing sour crudes & ability to deal with mercaptans.	Complying to future stringent emissions legislations in existing units with no or minimal equipment modifications.

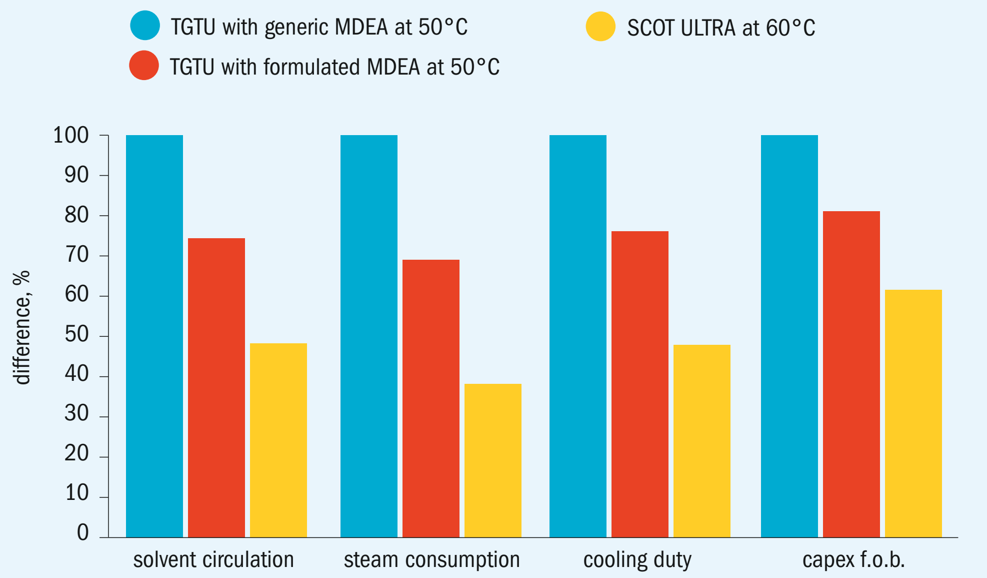
Source: Shell Global Solutions

Fig. 2: **Improvement in water gas shift and COS hydrolysis performance with C834 catalyst**



Source: Criterion Analysis

Fig. 3: **Relative operating expenditure for a generic amine TGTU (at 50°C) compared with SCOT ULTRA (at 60°C) technology**



Source: Shell Analysis

The combination of the new C-834 catalyst with the family of JEFFTREAT ULTRA solvents, brings a reduction of COS in the outlet of the reactor together with the H_2S content in the off gas from the SCOT absorber to extremely low values. The combination of the two effects results in a lowering of the overall SO_2 emissions from the incinerator and stack that are typically installed downstream of a TGTU.

The key components that make up the SCOT ULTRA process have already been successfully deployed and operated commercially, and offer potential performance advantages in both greenfield and brownfield applications (Table 1).

For the latter scenario, the simple replacement of the existing SCOT catalyst with C-834 together with a simple swap of solvent can improve the performance while the original plant design can be maintained.

Implementing these two changes not only potentially reduces the overall emissions from the facility; it also potentially provides the benefit of lower operating cost to the operator, as a dramatic reduction in circulation rate of the solvent can be achieved as well as lower operating temperatures for the SCOT reactor. In addition, due to the enhanced formulation of the solvent, lean amine cooling may not be required at facilities in warmer climates, which makes the requirement for refrigeration unnecessary. Furthermore, SCOT ULTRA line-up does not require the inclusion of a water-wash.

The following four sections look at the benefits in terms of the potential for reducing both the capital and operating costs associated with the installation of the SCOT ULTRA technology.

Benefits of C-834 catalyst

One of the primary benefits of the installation of the C-834 catalyst is the improved performance with respect to COS hydrolysis and hydrogenation in low temperature TGT applications. A key drawback of the recent development of the low temperature TGT applications, is the limitation that this has put on the ability to deal with COS in the tail gas of the Claus plant upstream. With the C-834 catalyst, there is a step change reduction in residual COS from the TGT reactor, thereby reducing the overall SO_2 emissions. This is clearly presented in Fig. 2, where the COS concentration in the outlet of the TGT reactor is shown to be reduced from 40 ppmv to 20 ppmv at lower operating temperatures. As the conventional solvents used in TGT units are not able to absorb COS, this can be considered to be a direct reduction in overall SO_2 emissions.

An additional feature of C-834 is the improved performance for the water gas shift reaction at lower temperatures, e.g. Fig. 2 shows comparable CO conversion, relative to C-734, at 20°C lower temperature.

In addition, due to its size and particle size distribution, C-834 can potentially offer up to 30% reduction of pressure drop across the TGT reactor relative to competitor's TGT catalysts, thereby providing benefits with its installation in plants where the capacity is constrained through pressure. This also means that using the C-834 catalyst could potentially be considered to increase the capacity of the sulphur recovery unit.

SCOT ULTRA technology economical evaluation

In addition to meeting more stringent emission regulations and having enhanced destruction of organic sulphur compounds,

Table 2: **Estimated performance of JEFFTREAT ULTRA, relative to DIPA and MDEA**

	DIPA	MDEA	JEFFTREAT ULTRA
H_2S in treated gas, ppmv	621	611	240
Relative solvent circulation rate, %	100	102	57
H_2S in recycle gas flow, mol-%	32.5	65.4	76.4
CO_2 slip, %	47	79	88
SRU flame temperature, °C	1,180	1,245	1,265

Source: Shell Analysis

operators can also benefit from lower operating costs when using a SCOT ULTRA line-up. The SCOT reactor can be run at a lower temperature, which gives the opportunity to prolong cycle length and reduce energy consumption by using indirect heating instead of line burners.

A significant reduction in solvent circulation rate, combined with improved H_2S removal performance at higher temperatures, is achieved in the SCOT absorber through the highly selective solvent JEFFTREAT ULTRA, which facilitates much lower energy requirements and translates into reduced steam, cooling and power costs.

To quantify the benefits, the impacts on capital and operating expenditure for the SCOT section through using the SCOT ULTRA process is shown in Fig. 3. A TGTU with a generic MDEA solvent and a TGTU with a formulated MDEA solvent operating at 50°C are compared with SCOT ULTRA technology at a 60°C solvent temperature. In this scenario, the solvent circulation rate can be reduced by 50% with the SCOT ULTRA technology compared with a TGTU using a generic MDEA solvent.

Operational Benefits due to SCOT ULTRA

The recycle stream from a SCOT unit can have a substantial effect on the operating temperature in the thermal reactor of an SRU. This is mainly caused by insufficient CO_2 slip in the SCOT absorber with DIPA or generic MDEA as the solution. In cases where ammonia destruction is a concern or where a substantial amount of BTEX is present in the acid gas to the SRU, this could lead to substantial operational problems such as plugging of the process piping and equipment with ammonium salts in the case of ammonia or severe fouling of the catalyst beds in the case of BTEX. The industry accepted minimum operating temperatures for the destruction of ammonia and BTEX are 2,300°F/1,260°C and 1,950°F/1,065°C respectively. The recycle gas stream from the SCOT regenerator can have a substantial effect on these temperatures and with the installation of the JEFFTREAT ULTRA suite of solvents, the selectivity of the absorption of H_2S over CO_2 can be improved in such a manner that there is a positive impact on the temperature in the thermal reactor. This is of particular interest in lean acid gas applications, where the reduction of CO_2 in the recycle gas can substantially improve this temperature if the CO_2 slip is maintained high.

Table 2 shows the differences in estimated performance of DIPA and MDEA relative to JEFFTREAT ULTRA.

Clearly, at a significantly lower solvent circulation deeper treat can be achieved at higher CO_2 slip with JEFFTREAT ULTRA.

Reduction of fuel gas to the thermal oxidiser

One final item that could be considered for the installation of SCOT ULTRA to improve the overall emissions of the facility, is the potential to reduce the total residual sulphur to a level where incineration of the off gas from the absorber is no longer a requirement. With the combination of the C-834 catalyst and the JEFFTREAT ULTRA suite of solvents, it is possible to achieve a H_2S concentration in the off gas from the absorber below 10 ppmv, which in a lot of jurisdictions can be vented directly to atmosphere. In this case, there is no longer a requirement to operate the thermal oxidiser and hence the unit can be kept in hot standby operation only, which results in substantial fuel gas savings to the facility. The thermal oxidiser can remain in this mode of operation for extended periods and only in cases where the H_2S content from the absorber does not meet the requirements of less than 10 ppmv would the off gas be routed to the thermal oxidiser for processing.

UCARSOL™ TGT for deep H_2S removal

The Dow Chemical Company (Dow) has developed and successfully demonstrated a novel series of solvents, UCARSOL™ TGT, which utilises new chemistry and unique formulations to target deep H_2S capture in low pressure environments, particularly refinery tail gas treaters.

Removal of residual hydrogen sulphide from low pressure sulphur plant tail gas has proved challenging for typical gas treating solvents such as MDEA at elevated lean amine or ambient temperatures, but Dow's improved MDEA-based solvents can meet aggressive treating objectives while allowing for online upgrades of existing systems. UCARSOL TGT is especially useful in high temperature environments, as its performance is less sensitive to ambient temperature than traditional gas treating amines, including other specialty formulated amines.

When compared to commodity MDEA, UCARSOL™ TGT offers an economically competitive alternative for reduction in sulphur emissions in high temperature regions and in plants wishing to mitigate daily or seasonal temperature influences on sulphur emissions.

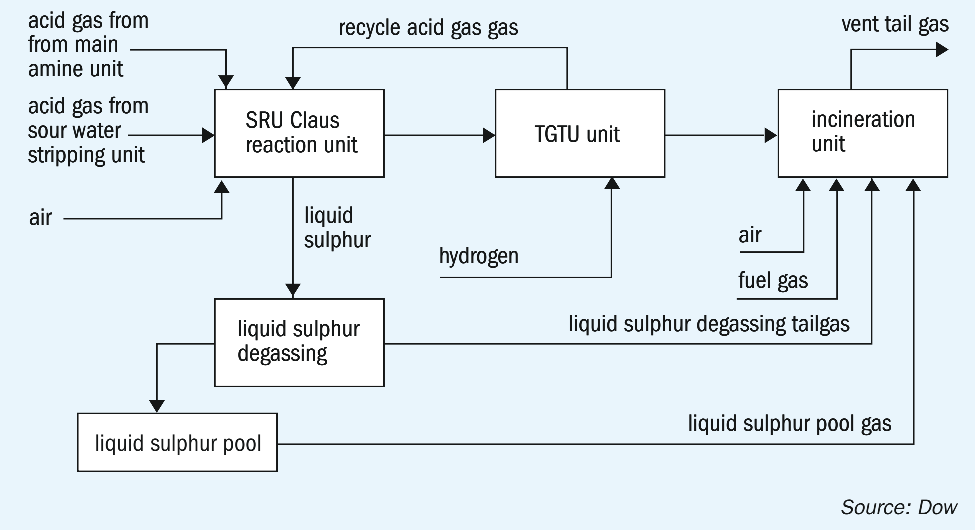
The performance of UCARSOL™ TGT series of solvents compared to MDEA has been evaluated and showcased in trials at a tail gas treater operated by China National Offshore Oilfield Company Huizhou Refinery Branch (CNOOC Huizhou) in Guangdong, China (Fig. 4).

Air quality specifications are becoming more stringent in China, and CNOOC Huizhou is taking proactive steps to meet the new SO_2 emissions requirements. Previously China's SO_2 emissions were limited to 960 mg/Nm³, but in July 2017 they were reduced to 100 mg/Nm³.

Trial conditions

The field trial was conducted in three phases, evaluating CNOOC Huizhou's existing solvent (MDEA) and two new Dow tail gas treating solvents (UCARSOL™ TGT solvents). For each solvent, only lean amine temperature was varied. Feed gas conditions, lean amine flow and reboiler duty were held constant (Table 3). This design ensured that the H_2S treating performance and temperature sensitivity of each solvent would be directly comparable. Amine concentration was kept similar for each solvent, although it varied between 28 and 38 wt-% amine throughout the trial.

Fig. 4: **Successful UCARSOL™ TGT solvent trial at CNOOC Huizhou Refinery in Guangdong, China, 2016**



Source: Dow

Table 3: **Tail gas treater conditions during field trial**

Date of trial	17/06/2016 to 11/11/2016
Inlet gas flow rate, Nm³/h	~ 7,000
Inlet gas temperature, °C	33-36
Inlet gas pressure, kPag	~9
Inlet gas composition, H_2S vol-%	~1
Inlet gas composition, CO_2 vol-%	~10
Lean amine feed tray	15
Lean amine temperature, °C	32.5-50
Lean amine temperature increment, °C	~ 2 per step
Lean amine flow rate, t/h	35-36
Reboiler duty (steam), t/h	~4.5

Source: Dow

After the initial phase of the trial, MDEA was removed from the system, and the system was flushed with demineralised water before adding the first formulation of the UCARSOL TGT series of solvents. The system was then converted to a second formulation of the UCARSOL TGT series of solvents. Dow was able to perform an online conversion to the second TGT solvent without interrupting tail gas treating. UCARSOL TGT formulations are fully compatible with MDEA-based systems. This online conversion capability of UCARSOL TGT is a key benefit to refineries where emissions are strictly monitored.

Plant trials often have complications including issues with instrumentation. The H_2S measurement on the outlet of the absorber did not work reliably. H_2S that slips through the tail gas treater together with other organic sulphurs (mainly COS) are later oxidised to SO_2. SO_2 is the sulphur species that is monitored and regulated. Due to the presence of online SO_2 measurement, the Dow/CNOOC teams chose to use SO_2 measurements as an analog for H_2S treating ability of the three solvents. The SO_2 approach has several challenges including the inability to account for the total sulphur mass balance from other process streams being fed to the incinerator, such as sulphur pit gas. Regardless, the SO_2 measurement approach is still useful as the majority of sulphur enters the tail gas treater and is in the form of H_2S. Other sulphur sources, although not directly quantified, were expected to be consistent throughout the trial leading to reliable comparative results. SO_2 measurements at CNOOC Huizhou were obtained via an online ABB Uras 14-AO2060 sensor.

Results

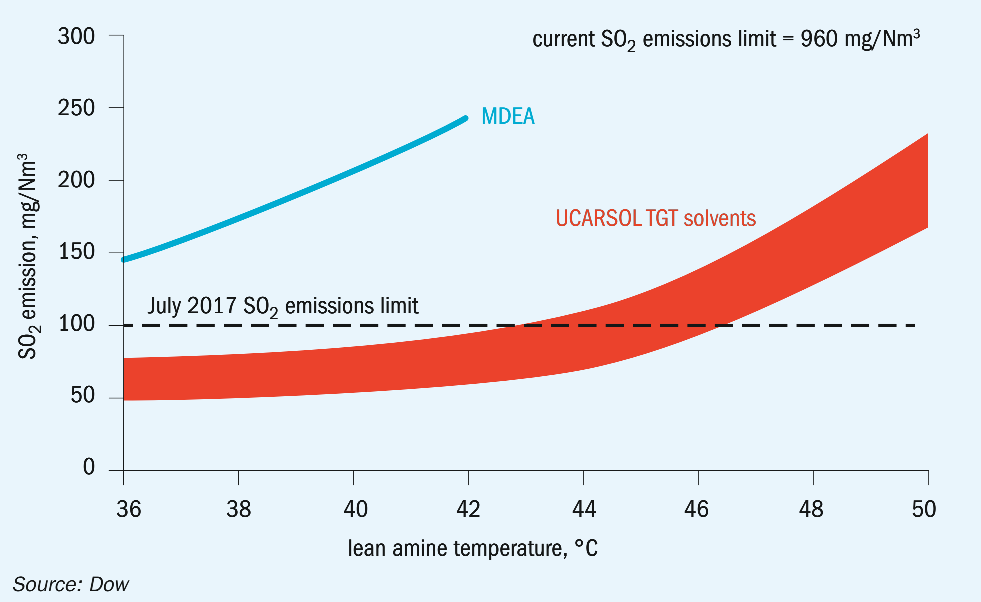
The CNOOC Huizhou tail gas treater operated smoothly with all three solvents. The plant was operated for two days at each lean amine temperature. This two day period per temperature ensured that the system obtained steady-state. Collection of multiple data points verified that the performance was repeatable, not subject to transient effects and has a minimum chance for systematic bias.

Both Dow UCARSOL TGT solvents were able to significantly reduce sulphur emissions compared to MDEA, particularly at elevated lean amine temperatures. UCARSOL TGT1 was shown to operate at 10-20% lower flow rate than MDEA without additional H_2S slip. The trial also demonstrated an online conversion to a UCARSOL TGT solvent without interrupting gas treating operations.

The SO_2 emission behaviour is plotted in Fig. 6. UCARSOL TGT solvents can be

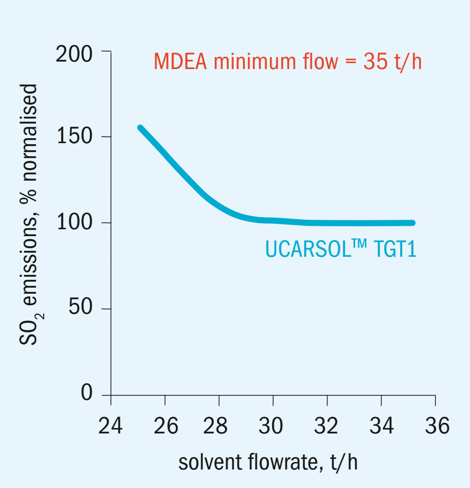
Fig. 5: CNOOC Huizhou Refinery in Guangdong, China.

Fig. 6: **SO_2 emission measurements vs tail gas treater lean amine temperature**



Source: Dow

Fig. 7: **UCARSOL™ TGT1 can operate at 10-20% lower flow than MDEA without additional H_2S slip**



Source: Dow

formulated to achieve ideal performance at various conditions. The UCARSOL TGT solvents reduced sulphur emissions by about 60-75% versus MDEA at 40°C, but asymptoted at temperatures below 40°C. This was due to background sulphur including COS, mercaptans, and sulphur from other process streams being fed to the incinerator. UCARSOL TGT solvents are less sensitive to high temperature due to their novel chemistry. This new chemistry allows UCARSOL TGT solvents to retain deep H_2S treat at very high temperature while still achieving deep H_2S treat at moderate and low temperature.

MDEA does not allow CNOOC Huizhou to meet new SO_2 emissions regulations below 100 mg/Nm³. Both UCARSOL TGT formulations treat the Huizhou refinery tail gas to levels that comply with the new targets. UCARSOL TGT provides the refinery with a wider lean amine operating range.

Both UCARSOL TGT solvents allow for more efficient operation versus MDEA – reduced solvent flow rates and/or reduced reboiler duty. However, solvent flow reduction was only quantified for one formulation, UCARSOL TGT1. A flow of 35 t/h was determined to be the minimum flow of MDEA without increased H_2S slip. UCARSOL TGT1 flow rate was reduced 10% less than MDEA with no measurable increase in H_2S slip (see Fig. 7).

Reducing UCARSOL TGT1 flow rate 20% versus MDEA to 28 t/h only led to a minor increase in H_2S slip.

Future TGT solvent testing will include optimised formulations enabling capital savings for new plants.

In general, a plant may choose to upgrade the solvent chemistry for a period of time during challenging emissions seasons. UCARSOL TGT solvents provide a wide operating range, stable operating performance, and will further benefit from onsite optimisation at the customer sites. No new hardware is required for the solvent conversion. No new operating procedures or safety considerations are required. No additional solvent storage is required.

S-Plus reducing Claus tail gas emissions

To meet China's recently imposed SO_2 emission regulations of less than 100 mg/Nm³, Keyon Process, a Chinese engineering company and a licensor of multiple sulphur recovery and sulphuric acid technologies, has developed "S-Plus", a combination of a Claus unit and a tail gas treatment unit based on the Keyon's patented DSR process. The general concept of S-Plus is shown in Fig. 8.

DSR stands for desulphurisation and SO_2 recovery. At the core of the DSR process is a unique solvent which selectively absorb SO_2 from Claus tail gas. The enriched DSR solvent is then regenerated by low pressure steam heating via a reboiler, releasing the SO_2 which is routed back to the Claus combustion chamber.

The chemical reactions are shown as follows:

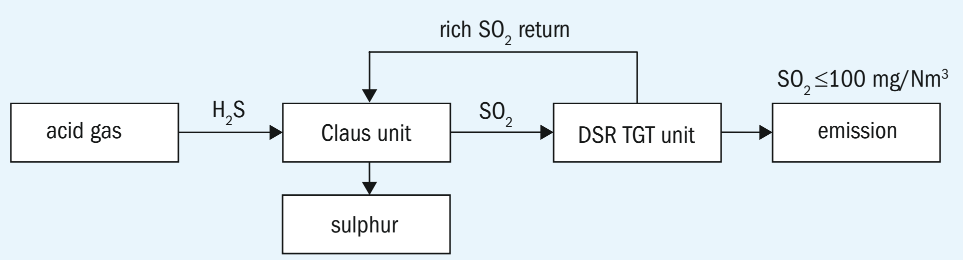
$$SO_2 + H_2O \rightleftharpoons H^+ + HSO_3^-$$

$$AB + H + HSO_3^- \rightleftharpoons AHSO_3 + HB$$

In the above equation, AB represents the absorbent (DSR solvent). The reaction is reversible. At low temperatures (40-60°C), the reaction proceeds to the right and SO_2 is absorbed. At high temperatures (105-120°C), the reaction is reversed and proceeds to the left for regeneration; SO_2 is released from the enriched absorbent, which regenerates the solvent so that it can be used repeatedly.

The DSR solvent AB is not a typical amine solvent, it is an organic salt solvent made from the neutralisation reaction between an organic acid and organic alkali. At low temperature, B^- is replaced

Fig. 8: **S-Plus flow diagram**

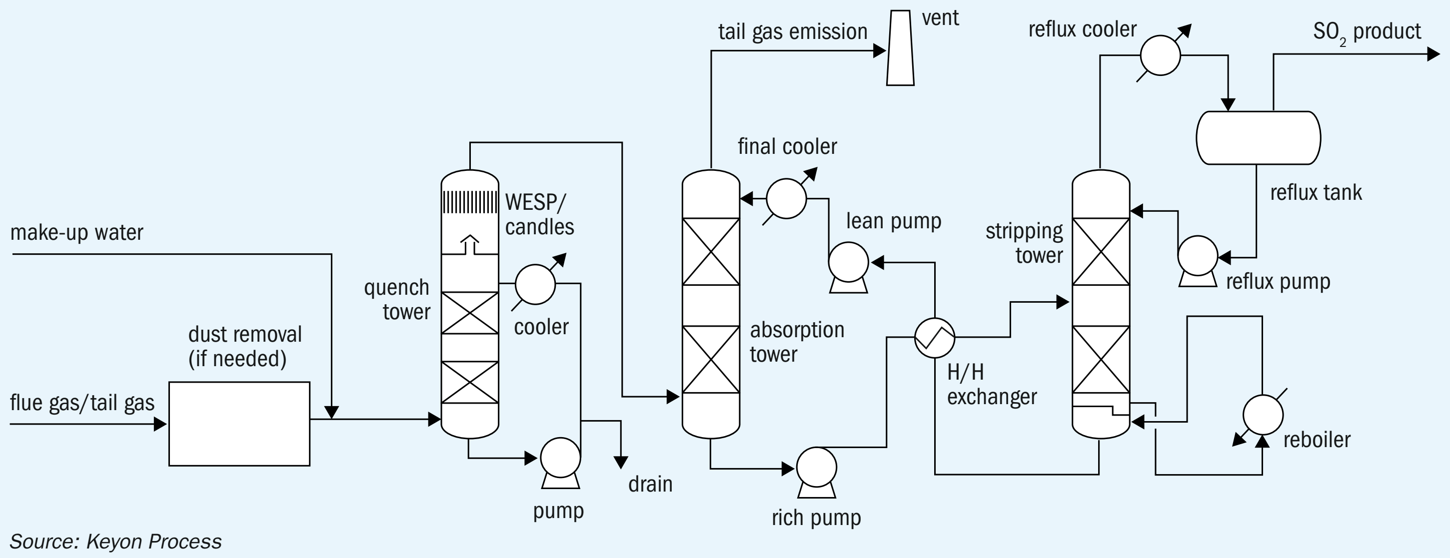


Source: Keyon Process

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46
47 48 49 50 51 52

Fig. 9: **DSR process diagram**



Source: Keyon Process

Table 4: **Comparison of the 50 t/d sulphur plant before and after the S-Plus revamp project**

	Before revamp (SCOT tail gas treatment)	**After revamp (DSR tail gas treatment)**
SO_2 final emission, mg/Nm³	~600	≤50
Sulphur recovery efficiency, %	~99.8	~99.9
Solvent circulation flow rate, m³/h	~30	~18
LP saturated steam (0.4 MPag) consumption for reboiler, t/h	4.55	2.05
Power consumption, kW	130.5	33.1
H_2 consumption, Nm³/h	30	0

Source: Keyon Process

by HSO_3^- that has greater acidity. HSO_3^- combines with A^+, forming $AHSO_3$ and stays in the solvent, which facilities the adsorption of SO_3^-. When the temperature increases to 90°C, $AHSO_3$ becomes unstable and releases HSO_3^-, then SO_2 desorbs from the solvent. In the meantime, B and A recombine, it helps to retain A in the solvent, with this, the solvent is regenerative.

Thanks to the great SO_2 adsorption ability of the DSR solvent, the S-Plus process is able to achieve 99.9+% sulphur recovery rate and low SO_2 emissions of <100 mg/Nm³ and even 50 mg/Nm³ of SO_2, an emission requirement which might be imposed in China after 2020. Fig. 9 shows the DSR process.

In 2017, the first S-Plus demonstration project for the revamp of a 15,000 t/a (50 t/d) Claus plant with SCOT tail gas treating unit was completed in China. The plant owner decided to initiate the revamp due to the following problems with the old SCOT unit:

- After years of operation, the hydrogenation unit was operating with low efficiency and channelling in the catalyst bed had formed shortcuts for the SO_2 flow which caused sulphur to form in the downstream equipment, blocking the strainer on the inlet line of the pump by the quench tower.
- SO_2 content in the SCOT off-gas was around 700-800 mg/Nm³, which is far greater than current emission standard.

The revamp project reused some of the old equipment such as the reboiler and incinerator but the existing columns were replaced due to corrosion problems and because the materials were not suitable for S-Plus operation.

The hydrogenation unit is no longer required, the process gas coming from the second sulphur cooler enters the existing incinerator in which all sulphur compounds such as H_2S and COS are fully converted to SO_2, which is later absorbed by solvent.

After revamping, the plant successfully started up and was operated in line with design parameters, especially for the requirement of emission control and energy consumption.

Table 4 compares operating data before and after revamping of the TGT section.

The advantages of S-Plus can be summarised by the following:

- shorter process flow, no hydrogenation step required;
- lower energy consumption - the flow of recycled solvent and steam consumption for solvent regeneration in the DSR unit are both lower than SCOT;
- cleaner emission, much lower SO_2 content in final emission gas of S-Plus compared to SCOT.

Following the good performance of the S-Plus demonstration plant, two more S-Plus based projects are now under design and construction, due to start-up soon. ■

References

1. van Son M. (Jacobs Comprimo® Sulfur Solutions) and Singoredjo L. (Shell Global Solutions): "Introducing the next step in tail gas treating: SCOT ULTRA", presented at Sulphur 2017 Conference, Atlanta, USA (Nov 2017).
2. Dugas R., Zhou A., Gu J., Oliveros Patiño G. and Badhwar A. (The Dow Chemical Company): "Lower sulfur emissions from refinery tail gas systems using improved solvents, field demonstration results", presented at Sulphur 2017 Conference, Atlanta, USA (Nov 2017).

1 47 2 48 3 49 4 50 5 51 6 52 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46

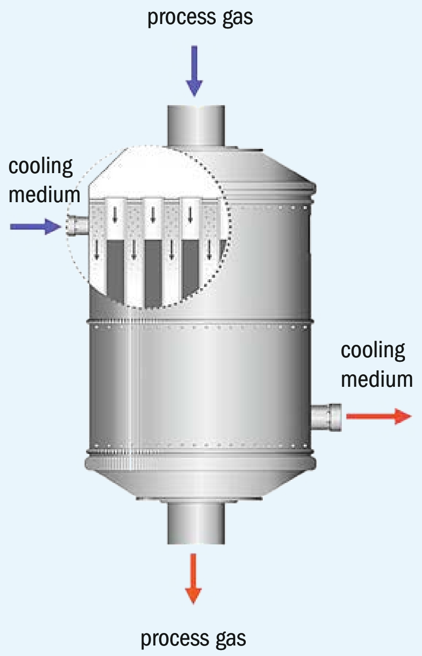
New approaches to acid plant design

New commercially proven concepts for the production of sulphuric acid are available for new and existing plants. Next generation sulphuric acid technology from Chemetics and MECS are discussed.

The sulphuric acid process has undergone little change in the last 40 years after the introduction of the double contact process. The standard sulphuric acid plant still mixes process gas containing SO_2 with air to create a gas with an SO_2 content in the range of 6-13 vol-% and an O_2 to SO_2 ratio above 1.0. The gas mixture then flows through a series of catalyst beds to oxidise the SO_2 to SO_3. Because the reaction is exothermic the temperature of the gas mixture increases. At higher temperature the equilibrium between SO_3 and SO_2 decreases, therefore inter-stage cooling and multiple catalyst beds are used to ensure high conversion rates are achieved.

SO_2 concentrations above 13 vol-% will lead to very high catalyst temperatures which irreversibly damage the vanadium pentoxide catalyst and must be avoided. With ever higher SO_2 concentrations generated using new or improved smelting and converting processes in the metallurgical and other industries there is a need for an improved process to convert SO_2 to SO_3.

Fig. 1: **CORE™ reactor schematic**



Source: Chemetics

Chemetics' answer to this problem is the cooled oxidation reaction (CORE™) system. In this process the oxidation reaction is carried out inside tubes with continuous cooling on the outside of the tubes.

Due to this continuous cooling the CORE™ reactor can achieve much higher (up to 97%) conversion in a single pass. At the same time the CORE™ process can also handle higher SO_2 (up to 50%) concentrations as the continuous cooling prevents the extreme temperatures hot spots that could damage the catalyst.

Chemetics' CORE™ reactor system

The heart of every sulphuric acid is the converter containing the catalyst that oxidised the SO_2 to SO_3. The CORE™ reactor consists of tubes filled with an oxidation catalyst mixture as shown in Fig. 1. Outside each tube a cooling medium flows through a defined channel in a co-current arrangement. The co-current arrangement provides maximum cooling in combination

Fig. 2a: **Adiabatic process**

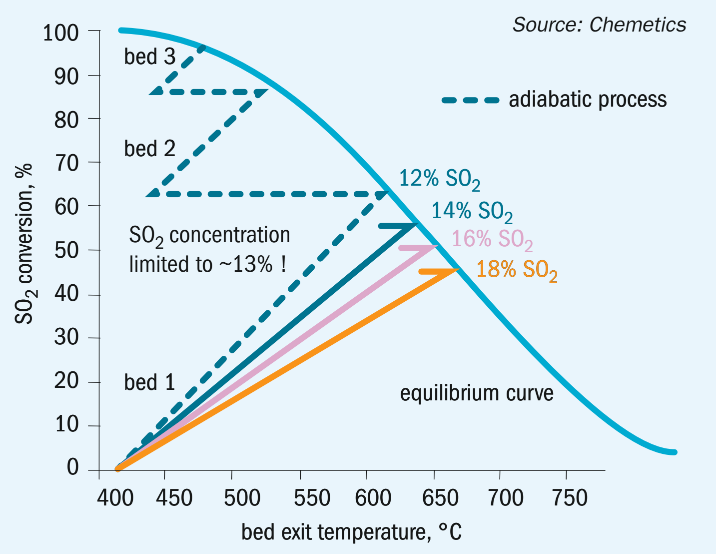


Fig. 2b: **CORE™ process**

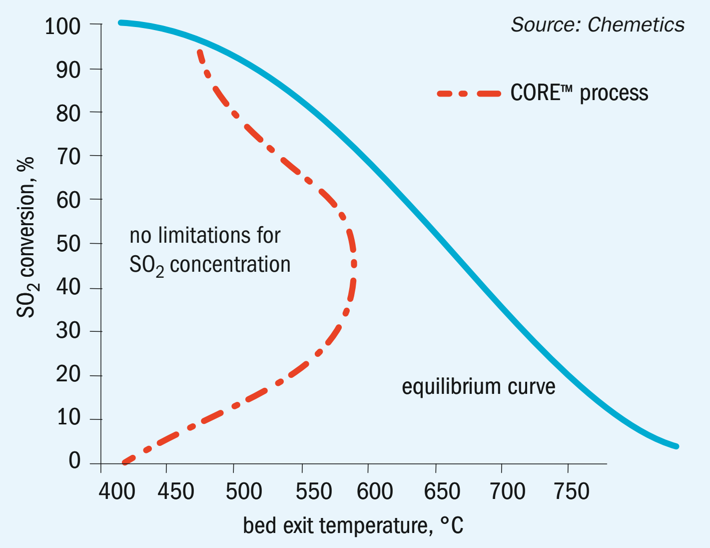


Fig. 3: **Basic CORE™ system**

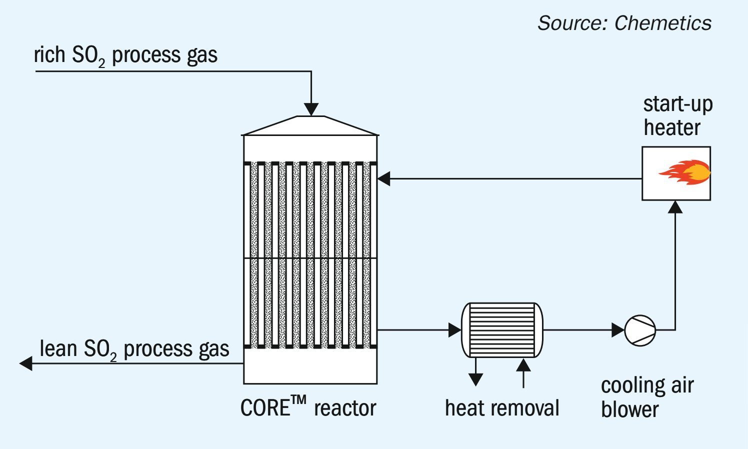



PHOTO: CHEMETICS

Fig. 4: CORE™ add-on system in operation.

with the desired temperature control which prevents creation of hot spots in the catalyst. The tubes are arranged on a triangular pitch. Creating uniform heat transfer conditions in the reactor is important and therefore great care is used to ensure proper process gas and cooling air distribution.

Reactors with less than 2,000 tubes are arranged using a cylindrical bundle geometry, whereas larger reactors are designed in a modular fashion with multiple carefully placed inlet nozzles to ensure proper distribution of the cooling medium amongst all the tubes. The catalyst activity can be varied to match the process conditions and is carefully selected to give high conversion while preventing excess temperature inside the tubes. The continuous cooling results in higher conversion in a single pass with no upper limit on the SO_2 concentration compared to the adiabatic process as illustrated in Fig. 2.

Most of the heat of reaction is transferred to the cooling medium and leaves the CORE™ reactor. This energy can then be used for generation of steam or to for heating other process streams. A heater is installed in the cooling loop to heat up the catalyst prior to start-up. The heater can also be used during short periods where the SO_2 concentration may drop below 6 vol-% where the process would no longer be auto-thermal. Fig. 3 shows the major components of a CORE™ reactor system.

The CORE™ reactor is compact in size with a height of no more than eight metres. This makes the reactor significantly shorter than an equivalent multi-bed adiabatic converter with three or more beds which often exceeds 15 m height.

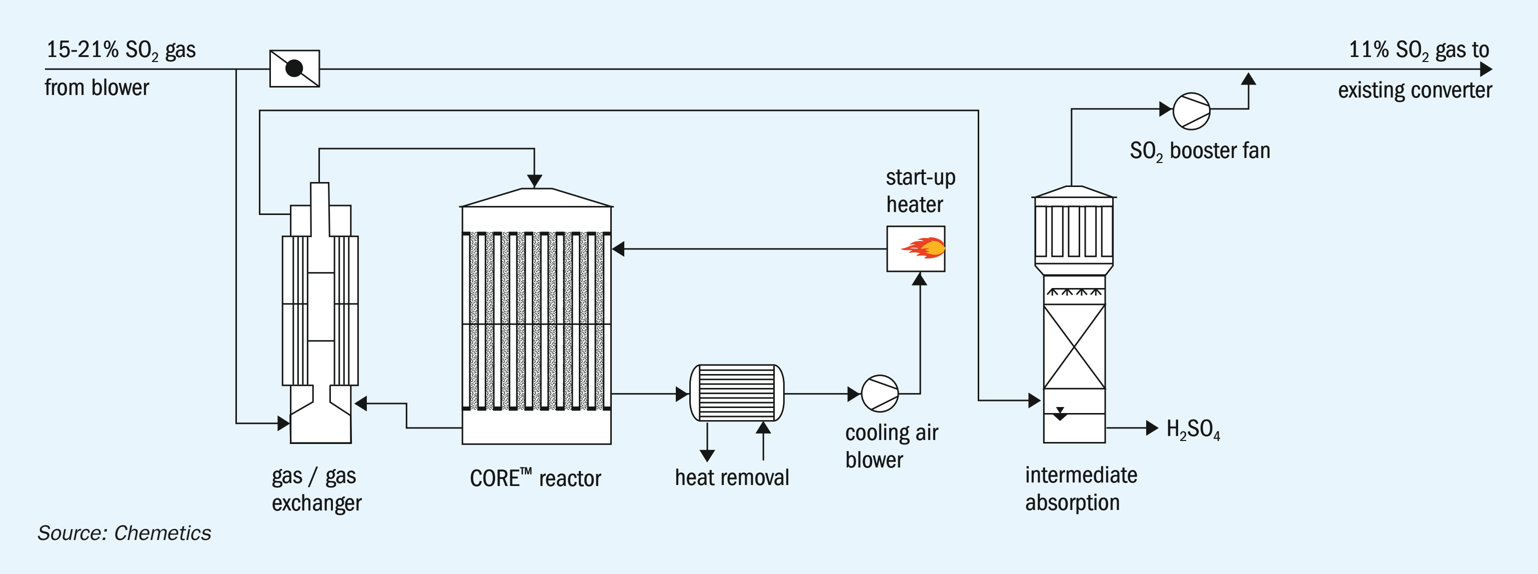
CORE™ add-on process

The CORE™ process is uniquely suitable as an add-on process for an existing metallurgical acid plant where capacity expansion in the smelting process by the addition of oxygen results in an off-gas with higher SO_2 concentrations. Dilution with air to the original design conditions of the sulphuric acid plant would result in a large increase in the process gas flow that could not be processed in the existing acid plant thus requiring either extensive modifications of the existing acid plant to handle this volume or more commonly the addition of a complete new sulphuric acid plant.

Instead, installation of a CORE™ add-on is a much simpler and more cost effective solution. Part of the gas from the smelter with high SO_2 concentration is diverted to the CORE™ add-on system after the drying tower.

First the gas is heated in a gas/gas exchanger using the hot gas leaving CORE™ reactor. The process gas at approx. 410°C then enters the CORE™ converter where 80-90% of the SO_2 is converted to SO_3 using air as the cooling medium. The hot process gases from the converter are cooled and the SO_3 is absorbed to form sulphuric acid in a standard absorption tower. A booster fan returns the gas to the main process stream for further processing in the existing acid plant (see Fig. 5). Sufficient process gas is diverted to the

Fig. 5: **CORE™ system in add-on configuration**



PHOTOS: CHEMETICS

Fig. 6: CORE™ reactor under construction: top and bottom vestibules (left), central tube section (right)

CORE™ system to maintain a constant SO_2 concentration of 10-12 vo-l% selected to match the design of the existing acid plant.

The CORE™ add-on system is a compact installation with few equipment items resulting in significant cost savings compared to the installation of a completely new sulphuric acid plant. In summary, the CORE™ add-on system offers the following benefits:

- increased sulphuric acid production without changing the gas flow through the existing acid plant(s);
- energy recovery in the form of steam or hot air;
- small foot print;
- system can be switched on or off as required by the SO_2 concentrations (ideal for plants where the SO_2 concentration fluctuates due to a batch process);
- constant SO_2 concentration to the existing acid plant resulting in less wear and tear on the equipment as temperature cycles are minimised;
- the sulphuric acid is a premium grade as the CORE™ absorption circuit is separate from the drying tower acid circuit where contaminants in the process gas can be transferred to the acid.

CORE™ add-on system operational experience

The CORE™ system in add-on configuration is currently operational at two locations in Europe. The first installation is at a lead smelter in Germany where a major smelter upgrade resulted in increased the SO_2 concentration in the process gas. Before the smelter upgrade the process gas with 10-12 vol% SO_2 was send to a conventional 3+1 DCDA Acid plant. After the upgrade the smelter now continuously produces a process gas with 18 vol-% SO_2. Changes in the lead concentrate can cause the SO_2 concentrations to fluctuate between approx. 15 and 23 vol-% during operation. A CORE™ system in add-on configuration was installed in 2009 to treat a portion of the process gas to maintain a constant 10 vol-% SO_2 concentration at the inlet of the original acid plant converter. Since 2009 the CORE™ System has been in continuous operation producing up to 450 t/d of premium grade sulphuric acid while processing smelter gas volumes up to 18,000 Nm³/h. High pressure steam is produced from the energy released in the CORE™ Reactor.

The entire plant was inspected after three and six years of operation. These inspections found that the CORE™ reactor was in pristine condition with no signs of internal or external corrosion. The inspection required removal of the catalyst which proved to be very easy using a vacuum system with no significant catalyst breakage. Based on the catalyst conditions at these inspections catalyst life in excess of ten years are expected.

The most recent CORE™ add-on installation is at a site which operates a batch copper smelter creating an off-gas with fluctuating SO_2 compositions. Improvements in the smelter have slowly increased the SO_2 concentration from the smelting process and the existing acid plant was limiting smelter production. After extensive studies it was decided that the CORE™ add-on system was the best choice for the fluctuating conditions. The CORE™ system for this site is designed to process up to ~35,000 Nm³/h process gas containing 14% SO_2. Energy released in the converter is discharged to the atmosphere in the form of hot air. Provision is made for the future retrofit of steam generation in the cooling air loop once demand for steam within the complex is increased. The CORE™ reactor was built in three sections in Germany (see Fig. 6) which were shipped to site for final assembly. Construction was completed in November 2016 and the plant was started in January 2017 with assistance from Chemetics. The plant achieved all performance guarantees during a performance test run in May 2017.

CORE-S™ system and process

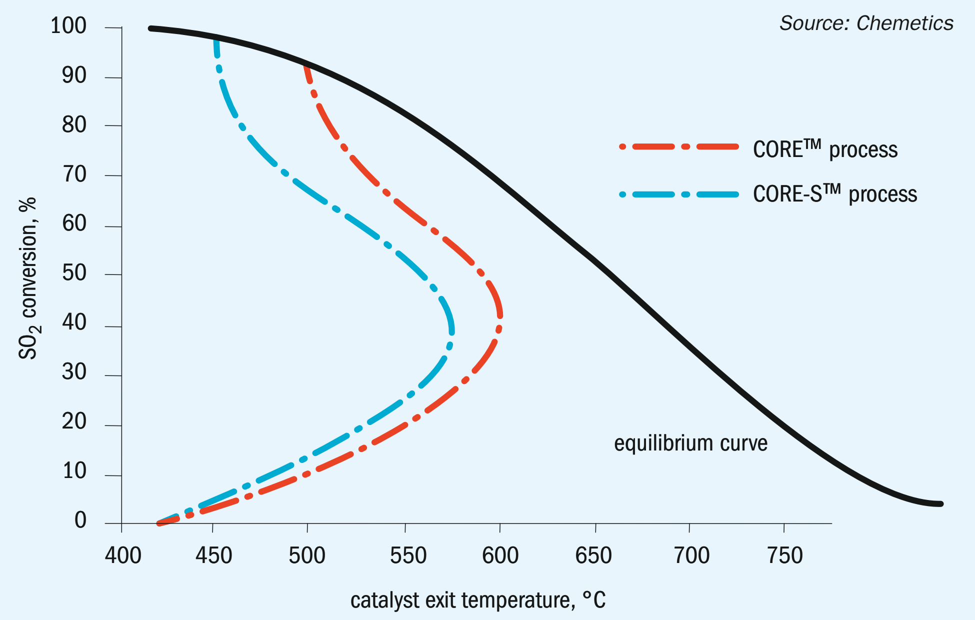
The CORE™ system with air cooling has been a very good process for these operators and will continue to be the best choice for smaller applications (gas flows up to ~40,000 Nm³/h). For larger plants, the use of air as the cooling medium results in higher energy consumption for the large cooling air blower and the size of the air ducts required for these plants requires larger plot space and more complex layouts.

Therefore, Chemetics has introduced CORE-S™, the next generation cooled oxidation reactor system, which utilises molten salt instead of air as the cooling medium. The use of molten salt for cooling offers the following additional benefits compared to the standard CORE™ process using air cooling:

- compact reactor cooling system reducing heat losses;
- lower energy consumption;
- higher conversion (up to 97%) due to lower process gas exit temperatures;
- smaller equipment for steam generation;
- smaller footprint;
- plant capacities of 400 – 3,000 t/d.

The use of the molten salt cooling system allows far more energy to be removed from the process gas due to the higher energy density of the molten salt. This means that

Fig. 7: **Comparison of catalyst temperature profile for CORE™ and CORE-S™**



the molten salt temperature increases much more slowly than is the case for an air-cooled system. The end result is that a significantly higher conversion rate can be achieved in a single CORE-S™ reactor compared to the basic CORE™ system as is illustrated in Fig. 7.

The CORE-S™ system can be used for all add-on applications where large gas volumes must be processed, but the CORE-S™ process can also be used as an in-line application for high SO_2 concentration process gas and therefore can be used as replacement for the traditional sulphuric acid plant design. For the in-line application, SO_2 conversion up to 97% can be achieved in a CORE-S™ reactor. After intermediate absorption the process gas still contains SO_2 in excess of current environmental legislation and further conversion in a single adiabatic catalyst bed, a regenerative scrubbing system using amine solvent (CANSOLV®) or chemical scrubbing system using e.g. peroxide is required to meet the required emission levels. Fig. 8 shows the CORE-S™ system in In-line configuration utilising and adiabatic catalyst bed to meet emission requirements.

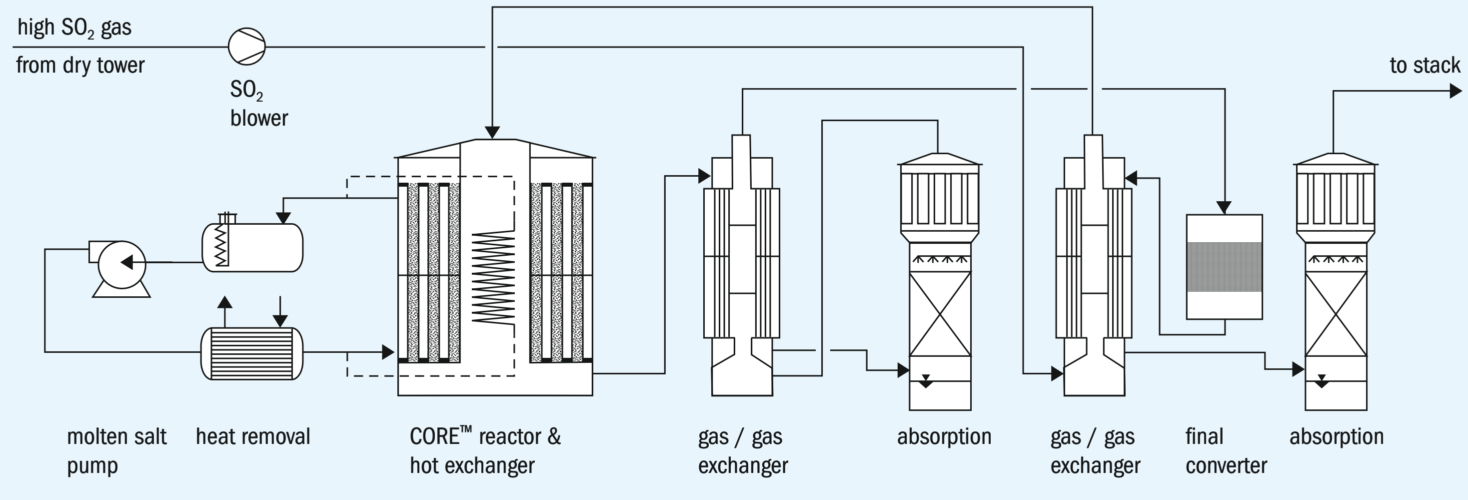
The in-line configuration is particularly advantageous for production of sulphuric acid from a regenerative scrubbing system (e.g. CANSOLV® System). In this application virtually pure SO_2 is received from the upstream regenerative scrubbing system which after dilution with ambient air results in a process gas mixture containing 20% SO_2 and 17% O_2. This gas is processed in the CORE-S™ Reactor and requires only a single absorption sulphuric acid plant. Because the acid plant tail gas can be returned to the upstream regenerative SO_2 scrubber there is no need for any secondary conversion and absorption and the plant size required is less than 50% of a conventional design. It is clear that this results in significant capex and opex savings.

Chemetics recently completed CORE-S™ plant design packages for both in-line and add-on configurations for plants with production capacities up to 2,000 t/d. These designs have been submitted to clients for final investment decisions. The lower investment cost for the CORE-S™ System provided by the ability to handle high concentration SO_2 gas offers compelling advantages for these projects compared to the conventional adiabatic designs.

In summary, the Chemetics' CORE™ / CORE-S™ process is a commercially proven technology for treating process gases with high SO_2 concentrations. For existing sulphuric acid plant operators, the CORE™ add-on process allows for cost effective production capacity expansion whereas for greenfield sites the CORE™ in-line process provides high plant capacities at reduced investment cost. Both processes provide the plant owner with the following key benefits:

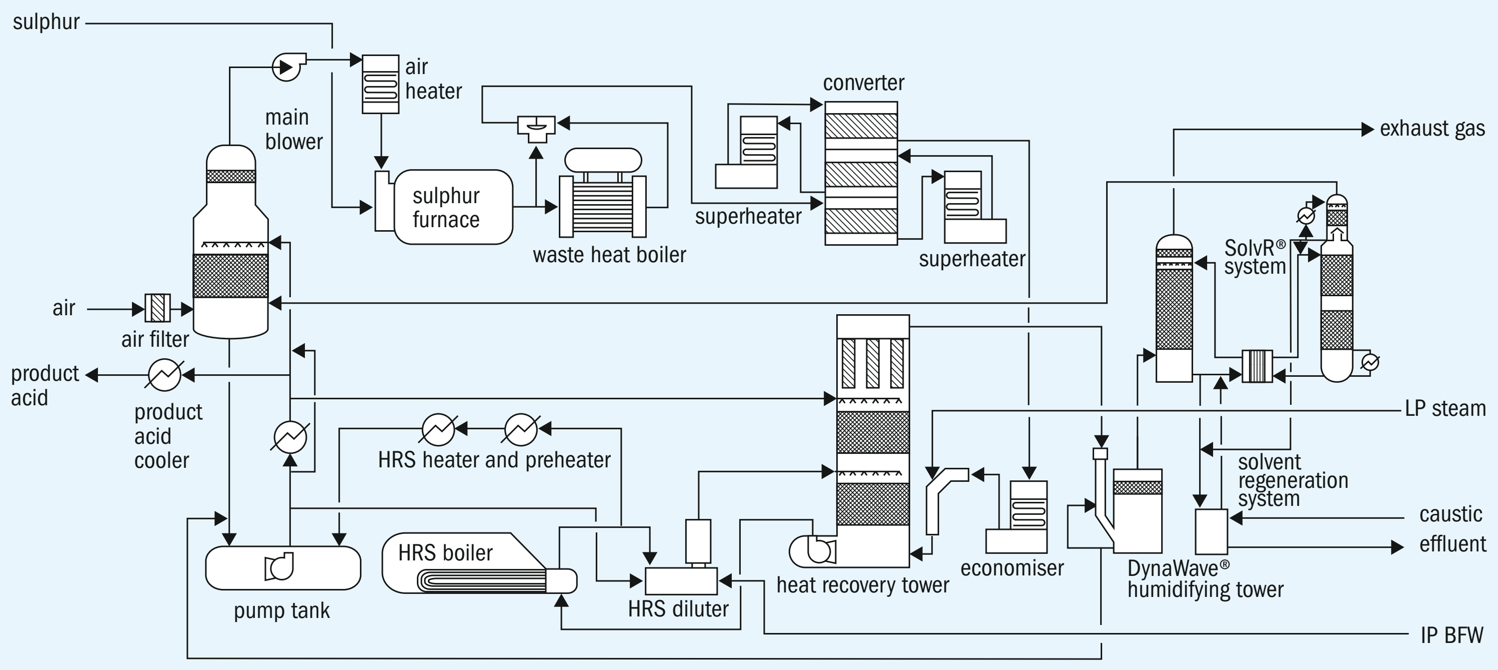
- reliable processing of off-gases with high SO_2 concentration and low O_2:SO_2 ratio;
- easy start-up/shutdown and long term hot standby capability;
- high conversion rates
- premium grade acid produced;
- low maintenance requirements;
- small foot print;
- low capex;
- low opex.

Fig. 8: **CORE-S™ in-line system with secondary catalytic conversion**



Source: Chemetics

Fig. 9: **MECS® MAX3™ flow scheme**



Source: MECS

MECS' next generation sulphuric acid plants

Sulphuric acid plants often operate for several decades so industry investment decisions usually consider a combination of capital cost, operating cost, and long run emissions. MECS has long compiled feedback from the sulphuric acid industry to identify trends that can be used to drive long term innovation. And while capital cost has always been important, the global sulphuric acid industry has increasingly pushed for improved energy efficiency, reduced emissions, and new ways to upgrade or replace its aging assets. With difficult trade-offs guiding the choices available to sulphuric acid producers, MECS foresaw that a novel approach would be required to simultaneously improve emissions and reduce capital and operating expenses.

With this target over the past eight years research and development work at MECS has had a strong focus on improving sulphuric acid technology to comply with emissions and effluent reduction targets, while balancing productivity and profitability. Previous approaches to simultaneously minimise capital expenditures (capex), operating expenditures (opex), and emissions proved unsuccessful because of technology limitations. MECS started off by reviewing all areas in a sulphuric acid plant that consume time, water and money, as well as all drivers of emissions, both liquid and gaseous. As a result, the MECS R&D team has developed a novel approach that eliminates or at least reduces high consumers of time, water and money while also recovering more energy – all at best in class emissions.

The result is MAX3™ – a proprietary sulphuric acid plant technology that simplifies the conventional sulphuric acid plant flow scheme by combining a single absorption HRS™ plant with MECS' SolvR® regenerative SO_2 scrubbing technology (see Fig. 9). It eliminates equipment, cuts cost and increases efficiency. In a MAX3™ plant, the use of SolvR® makes it possible to achieve close to zero SO_2 emissions. SolvR® also improves operating flexibility, capital and operating costs. It economically removes SO_2 from gases with concentrations as low as 300 ppmv and as high as 50 vol-%, reducing SO_2 emissions below 30 ppmv. If even lower limits are required, additional regenerative steam can be used to reduce SO_2 emissions below 10 ppmv.

Industry background

MECS has licensed its ClausMaster™ regenerative scrubbing technology for many years, with more than ten references in a wide variety of applications. While the ClausMaster™ technology had successfully demonstrated the ability to remove SO_2 from gaseous waste streams, the MECS R&D team believed an improved solution could be more effective. In the late 2000s, MECS reviewed ClausMaster™'s most glaring limitations and set out to develop an improved solvent that would be readily available worldwide, would allow for the use of lower cost materials of construction, and would be designed to operate in the "sweet spot" of tail gas emissions from a single absorption sulphuric acid plant. This effort began with an extensive search of physical property databases to identify families of solvents meeting MECS's rigid performance criteria. Next, a worldwide intellectual property review led to a determination that preliminary work would lead to the development of a technology that was both free from infringement risk and also could be patented. Pilot plant tests verified the performance of the solvent, in both SO_2 removal efficiency and resistance to corrosion. MECS's upgraded regenerative technology was named SolvR® and was ready for commercialisation.

SolvR®

MECS's SolvR® technology, first commercialised in 2014 at a sulphur burning plant in the United States, follows the same principles of unit operations as the ClausMaster™ process. Tail gas from a sulphuric acid plants is adiabatically hydrated in a DynaWave® scrubber and flows into a countercurrent absorbing column, where SO_2 is absorbed into a circulating flow of solvent.

PHOTOS: MECS

Fig. 10: Southern States commercial SolvR® plant.

Clean gas exits the absorber at the top, and the rich solvent is pumped to a stripping tower which removes SO_2 by steam stripping. SO_2 is recycled to the front end of the sulphuric acid process, and lean solvent is pumped to the top of the absorbing tower. MECS also provides a solvent regeneration system to remove sulphates that will accumulate over time. Effluent from the SolvR® system is a weak aqueous sodium sulphate solution that can either be sent to battery limits or concentrated to produce higher grades of sodium salt. It should be noted that SolvR® is an upgrade over ClausMaster™ for several reasons. First, the SolvR® solvent does not require high-grade stainless steel materials, leading to a significant reduction to the cost of the system. Further, the SolvR® solvent is readily available and is much lower cost than other regenerative solvents used to remove SO_2. Finally, steam consumption is less than in the ClausMaster™ process. And while the SolvR® system is a net consumer of energy, steam injection can be used to closely integrate heat recovery between the SolvR® and the acid plant in a breakthrough way.

Steam Injection

Steam injection, a technology first commercialised by MECS nearly 20 years ago, offers an economically advantageous method for maintaining concentration control in the HRS acid system. A portion of the water required for concentration control is provided through the steam injection vessel, and the remainder is provided in the HRS diluter. Low pressure steam is injected into the process gas in a steam injection chamber upstream of the heat recovery tower. Since the overall enthalpy of the water fed to the HRS is higher when steam is used, the latent heat from condensation boosts generation of HRS steam compared to HRS designed without steam injection. Effectively, steam injection upgrades low pressure steam that would otherwise be vented to atmosphere.

About eight years ago MECS introduced a step change improvement to steam injection called SteaMax™. In SteaMax™ HRS designs, MECS uses an even higher steam to liquid water ratio for dilution, approaching operation with little or no liquid water for dilution. This configuration multiplies the enthalpy effect of conventional steam injection, allowing most plants to realise gains in absorption heat recovery of 20-30% over a conventional HRS with steam injection. But the most important benefit of SteaMax™ has been unrealisable until the development of SolvR®. Combining these two technologies leads to MECS' new process: MAX3™.

MAX3™

Combining a single absorption sulphuric acid plant with SolvR® leads to both gains and losses with respect to heat integration. Additional heat is recovered because the interpass heat exchangers are not required in a single absorption sulphuric acid plant. But SolvR® consumes both low pressure steam and cooling water, so is there a way to integrate all of these technologies to offset utilities required in the SolvR®?

To solve this problem, MECS design engineers first started with the principle that essentially each kilogram of low pressure steam fed to the steam injection chamber is upgraded to ~10 barg steam in the HRS. While this is true in theory, it has been difficult to achieve in practice because few sulphuric acid plants have excess 2 barg steam available for steam injection. And the requirement for SolvR® to consume 2 barg steam would seem to leave no opportunity for integration. But it is these two fundamental challenges that the MAX3™ process overcomes to simultaneously reduce capital cost, operating cost, and emissions.

By integrating the SolvR® and SteaMax™ systems, MECS shifts a portion of the steam produced in an HRS acid plant to high pressure steam, while upgrading LP to HP steam inside the HRS, a benefit that has been unachievable with conventional acid plant technologies. At the same time, the MAX3™ process is able to achieve this upgrade at emission levels that are an order of magnitude lower than conventional designs.

MECS sold its first MAX3™ plant in 2015 and its second in 2016, and in both cases MECS successfully leveraged the flexibility of the SolvR® regenerative system to design unique configurations for each customer that minimised costly utilities and maximised profitable exports on a site-specific basis. These custom designs would not have been possible using conventional acid plant technology, which is typically restricted to a single configuration with only the ability to make small modifications. In moving the industry towards more customisation, MAX3™ offers sulphuric acid producers the flexibility to evaluate numerous designs so that each new acid plant can be as profitable as possible. ■

References

1. Dijkstra R. (Chemetics): CORE™ – A new approach to sulphuric acid plant design", Sulphur 2017 Conference, Atlanta, USA (Nov 2017).
2. Viergutz M. (DuPont Clean Technologies): "The next generation of sulfuric acid technology", Sulphur 2017 Conference, Atlanta, USA (Nov 2017).

Advertisers' index

Advertiser	Page	Website
Ametek Process Instruments	13	ametek.com
Dupont Clean Technologies/MECS	5	dupont.com/products-and-services/clean-technologies
Enersul Limited Partnership	OBC	enersul.com
Fluor Corporation	IFC	fluor.com
HUGO PETERSEN GmbH	9	hugo-petersen.de
IPCO Germany GmbH	11	IPCO.com
Jacobs/Chemetics	17	jacobs.com/chemetics
Jacobs Comprimo Sulfur Solutions	29	jacobs.com/comprimo-sulfur-solutions
Sulphur 2018 Conference	41	events.crugroup.com/phosphates/home
Weir Minerals	19	global.weir/brands
ZAFARAN Industrial Group Co.	IBC	zafaran.net

Distribution at:
Sulphur 2018 Conference, Gothenburg
MESPON Middle East SOUR Plant Operations Network 2018, Abu Dhabi

Next issue: September/October 2018

- The logistics of sulphur exporting
- Europe's sulphuric acid exports
- Using sulphur to store renewable energy
- Sulphur handling and forming
- Energy efficiency in the SRU

Closing date for advertisement space booking is 6 September 2018
For further information and to book advertisement space contact:
Tina Firman, Publishing Director: tina.firman@bcinsight.com
Tel: +44 (0)20 7793 2567 Fax: +44 (0)20 7793 2577

Editor: RICHARD HANDS
richard.hands@bcinsight.com

Technical Editor: LISA CONNOCK
lisa.connock@bcinsight.com

Contributor: OLIVER HATFIELD
oliver.hatfield@integer-research.com

Publishing Director: TINA FIRMAN
tina.firman@bcinsight.com

Subscription rates:
GBP 440; USD 880; EUR 680

Subscription claims:
Claims for non receipt of issues must be made within 3 months of the issue publication date.

Sales/Marketing/Subscriptions:
MARLENE VAZ
Tel: +44 (0)20 7793 2569
Fax: +44 (0)20 7793 2577
marlene.vaz@bcinsight.com
Cheques payable to BCInsight Ltd

Advertising enquiries:
TINA FIRMAN
tina.firman@bcinsight.com
Tel: +44 (0)20 7793 2567

Agents:
Japan: (also subscription enquiries)
KOICHI OGAWA
O.T.O. Research Corporation
Takeuchi Building
1-34-12 Takadanobaba
Shinjuku-Ku, Tokyo 169, Japan
Tel: +81 3 3208 7821
Fax: +81 3 3200 2889

Previous articles from *Sulphur* from 1995 to the present are available digitally in PDF format. To make a purchase, or for a list of available articles, please see: www.bcinsight.com

ISSN: 0039-4890

Design and production:
JOHN CREEK, DANI HART

Printed in England by:
Buxton Press Ltd
Palace Road, Buxton, Derbyshire, SK17 6AE

BCInsight

Published by: BCInsight Ltd
Southbank House, Black Prince Road
London SE1 7SJ, England
Tel: +44 (0)20 7793 2567
Fax: +44 (0)20 7793 2577
Web: www.bcinsight.com
www.bcinsightsearch.com


ModEx
Remelting Solutions
GX SERIES
GX™ Granulation
WETPRILL
WetPrill™ Forming
PRO-PIVOT
Block Pouring
Technical Solutions
Operational Services
Aftermarket
Liquid Storage
Solid Storage
STS
SafeFoam Transfer System
Transportation Loading
HYSPEC
Degassing
FEED Studies
EPC Support
Training
HSE Specialists
Rail
Ship
Truck
Bag