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 53 54 55 56 57 58 59 60 61 62 63 64

Number 345

January | February 2017

nitrogen+syngas

www.nitrogenandsyngas.com

Welcome to our iPad version of Nitrogen+Syngas Issue 345

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.

X CLOSE COPYRIGHT NOTICE

Nitrogen in Southeast Asia

Nitrogen project listing

Early detection of process risks

Ammonia catalysts

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 53 54 55 56 57 58 59 60 61 62 63 64

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 53 54 55 56 57 58 59 60 61 62 63 64

nitrogen+syngas

www.nitrogenandsyngas.com

NUMBER 345
JANUARY | FEBRUARY 2017

Cover: *Balinese statue. 35007 / iStockphoto.com*

20

Southeast Asia

Becoming a nitrogen exporting region.

52

Catalyst changes

A good time to review your ammonia process.

Read this issue online at: www.nitrogenandsyngas.com

Published by:
BCInsight

CONTENTS

REGULARS

Not a bargain

> **"Ukraine's troubles go back much further than 2014.**

The Ukrainian government's failure to secure even a single bid for the Odessa Port Plant (OPZ) in its recent attempted sale is a sad reflection on the decline of Ukraine's nitrogen fertilizer industry. Until just a couple of years ago, Ukraine was the third largest exporter of ammonia in the world, after Russia and Trinidad, and the fifth largest exporter of urea, but that position has slipped as exports have gradually dried up.

The Ukrainian government first attempted to sell OPZ, which has 900,000 t/a of ammonia and 660,000 t/a of urea capacity, back in 2009. However, the $624 million winning bid, by Ukrainian firm Nortima, was disallowed by the government of Yulia Timoshenko, alleging 'conspiracy'. The matter rested (aside from Nortima's legal challenge) until the deposition of president Victor Yanukovich in 2014 brought Ukraine back into serious conflict with Russia. Since then Ukraine has lost the Crimea and part of the east of the country to Russian-backed separatists and seems its economy nosedive, requiring a bail-out from the International Monetary Fund which in turn has led to the current round of privatisations to try and raise money. The second attempted sale of OPZ began in July 2016, but this time attracted no interest, and the government dropped the floor price for bids for a 99.6% share of the company from its original pitch of $530 million to just $200 million. Ten potential buyers were said to be "interested". However, OPZ still also owes $200 million to Naftogaz and Group DF over unpaid gas debts, and in spite of government attempts to assume or restructure this debt, concerns about other legal entanglements – including Nortima's disallowed bid – also put investors off. OPZ was shut down during August and September due to gas and debt disputes, losing $300,000 per month, and while the company made a profit of $8.1 million in 2015, this dropped to a $16.1 million loss for 1Q 2016. OPZ's gas contract with Nafotgaz expires in December, and news about renegotiation was also thin on the ground.

Ukraine's troubles go back much further than 2014, however. After the breakup of the Soviet Union, with Ukraine a net recipient of Russian gas, fights over gas supplies and pricing have been endemic, with accusations of Ukraine illegally siphoning gas from transit pipelines and not paying for gas it had received, leading to several major shutdowns of supply. Russia's Gazprom has gradually pushed its gas prices to Ukraine upwards to the same level that it sells into the rest of Europe, a point at which Ukraine's nitrogen fertilizer industry was no longer competitive. As a result, the industry had to rely on government subsidies or – in the case of Group DF/Ostchem, run by (now exiled) pro-Russian businessman Dmitry Firtash – personal contacts with Russia to secure more favourable rates. Since 2014 Ukraine has gradually let gas supply contracts with Gazprom lapse and instead bought gas from Western Europe secured at generous subsidised rates, now amounting to two thirds of Ukraine's imports. Even so, much of Western Europe's gas has in turn come from Gazprom, and even with the fall in global gas prices due to the oil price crash, wholesale gas is currently crossing the Slovakian-Ukrainian border at $5.50/MMBtu. Meanwhile, Ukraine's economy has almost halved since 2013 and it is now spending 8% of GDP on gas subsidies alone. The fighting in the east of the country has shut down two of its fertilizer plants, and gas pricing and availability is affecting the rest. Small wonder that investors stayed away from the OPZ sale!

Even if Ukraine's disputes with Russia were to end tomorrow, average gas prices in the country were still $7.80/MMBtu for the first half of 2016, according to Integer Research, putting it at the top end of the cost curve for nitrogen producers, as gas prices had fallen further in other regions. In an oversupplied market with ample coal-based supply from China fighting for market share and the US re-starting domestic plants based on cheap shale gas, the future for what was once the world's third largest ammonia exporter continues to look bleak. ■

Richard Hands, Editor

1 47 2 48 3 49 4 50 5 51 6 52 7 53 8 54 9 55 10 56 11 57 12 58 13 59 14 60 15 61 16 62 17 63 18 64 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

Price trends

MARKET INSIGHT

Laura Cross, Senior Analyst, Integer Research, assesses price trends and the market outlook for nitrogen.

NITROGEN

Explanations for the recent modest uptick in urea prices are varied. Seasonal increases in urea demand are important, but the role of China as a swing supplier means Chinese production costs have been the main focus of attention. As one of several measures targeted at making the gas sector more transparent, China's National Development and Reform Commission (NDRC) is reported to have liberalised gas prices to the fertilizer sector from 10 November 2016. Since much of China's gas-based urea capacity is already struggling, the impact of this measure on the international urea market is likely to be relatively insignificant. In addition, since most of China's urea capacity is coal-based, coal market developments tend to have a more profound urea market impact. Government measures introduced to the coal sector earlier this year to deal with the structural over-capacity in coal production have had a significant effect on coal prices, until now. A directive to reduce the number of days per year that coal mines can operate from 330 to 276, has shortened the market, driving up the price of coal, coking coal in particular. The rise in coal costs has in turn squeezed Chinese coal-based nitrogen producer margins, forcing operators to further idle capacity, and effectively raising the urea export price floor. This has been helpful for international urea producers elsewhere. However, this glimmer of positive news may well be short-lived. In late November, reports indicated that limits on coal output would remain in place until March, but this week it has been reported that curbs will be reversed. The NDRC is now saying mines will be allowed to go back to production rates of 330 days per year until March. In addition, it has been reported that the coal supply surplus will be alleviated by allowing increased exports. If implemented, this would likely bring a direct and parallel effect on the urea market.

In a reversal of roles, the urea market remained firmer than the ammonia market over the last quarter. The Yuzhnyy ammonia benchmark notably fell below the post-financial crisis low of $182/tonne f.o.b. which was recorded in July 2009, averaging $168/t in October 2016. The urea market appeared to be firmer, as the Yuzhnyy urea price rebounded over Q3 2016 before reaching $190/t in October 2016. The modest price gains have been supported by a seasonal uptick in urea demand, and China's role as a swing supplier. The nitrates market also seems to have picked up. The AN Baltic Sea benchmark followed the trend of urea throughout Q3 2016 and began to trend upwards, with the price reaching $173/t in October.

On the cost side, global energy prices continued to rally over Q3 2016, with European gas prices continuing to slide amid increased competition and continued oversupply, while the US gas market showed a moderate recovery in line with oil prices. The Russian border gas price in Germany fell by 39% year-on-year in October to $3.96/MMBtu. The Russian gas price reflects Gazprom's increasingly aggressive pricing policies in Europe, given the continued liberalisation and increased gas competition from other suppliers.

The largest year-on-year decrease in nitrogen production costs was seen in Northwest Europe. Typical ammonia ex-works costs for European producers fell by $70/t year-on-year to $185/t in October 2016, primarily due to a fall in hub-based feedstock gas costs. Local gas benchmarks including the UK NBP and Belgian Zeebrugge continued to fall on increased competition in the European gas market and rise of LNG imports, including those from the US.

In China, the ex-works urea production cost of anthracite coal-based capacity returned to around $180/t in October 2016 due to higher coal prices, after falling to $155/t in Q2 and Q3 2016. The Chinese ex-works production cost was on average $2/t higher in October 2016 than in the previous year, aided by currency depreciation of the US dollar relative to the yuan. The regions which are typically seen as the lowest cost producers historically, posted the highest increases in typical urea ex-works costs per tonne in October. The typical urea ex-works cost per tonne in Saudi Arabia increased by $10 to $74/t in October 2016, compared with the same month in 2015, primarily due to an increase in the state fixed gas price in Saudi Arabia from 1 January 2016.

The Russian ex-works urea cost remained unchanged in October 2016 on average compared to the previous year, despite falling over the course of this year. The industry had expected that the state-regulated gas price of RUB119/MMBtu would rise by 2% in line with inflation from 1 July 2016, however the gas price remains unchanged since 1 July 2015. Ukraine benefited from the diversification away from Russian gas imports towards competitively priced reverse gas imports from Europe to secure lower feedstock prices, coupled with a significant depreciation in the local currency. Ukrainian ammonia producers recorded a fall in ex-works costs of $88/t year-on-year in October 2016 to $330/t. ■

Table 1: **Price indications**

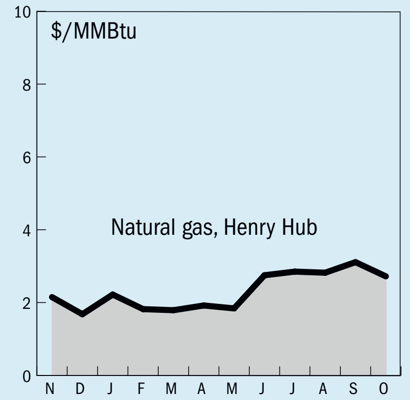
Cash equivalent	mid-Nov	mid-Sep	mid-Jul	mid-May
Ammonia ($/t)				
f.o.b. Caribbean	175	195	245	280
f.o.b. Arab Gulf	175	165	305	335
c.fr N.W. Europe	245	230	295	358
c.fr India	187	225	340	383
Urea ($/t)				
f.o.b. bulk Black Sea	219	190	176	201
f.o.b. bulk Arab Gulf*	238	181-193	173	190-199
f.o.b. bulk Caribbean (granular)	213	194	167	215
f.o.b. bagged China	236	196	197	209
DAP ($/t)				
f.o.b. bulk US Gulf	323	339	340	345
UAN (€/t)				
f.o.t. ex-tank Rouen, 30%N	145	137	135	138

Notes: n.a. price not available at time of going to press
*n.m. no market   * high-end granular*
Source: Fertilizer Week

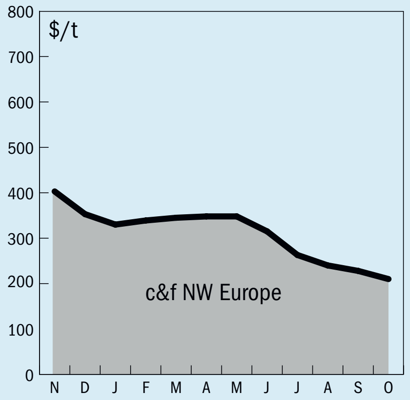
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46
47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64

END OF MONTH SPOT PRICES

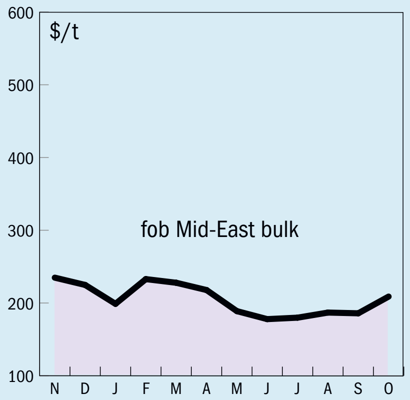
natural gas



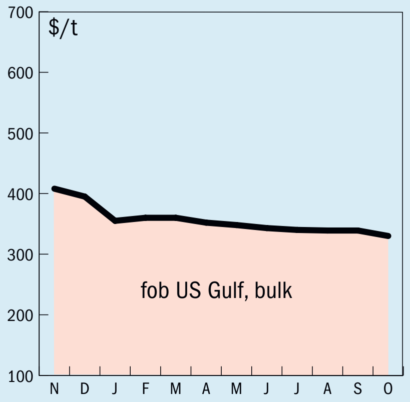
ammonia



urea



diammonium phosphate



MARKET INSIGHT

Mike Nash, Global Business Director, IHS Chemical, assesses the market for methanol.

METHANOL

The September contract natural gas reference price was settled at $2.44/MMBtu for Texas, and $2.85/MMBtu for Louisiana, down $0.45 from October. Methanol demand in the Americas is at a seasonal low for construction, although the cold weather does drive anti-freeze and windshield wash demand. Overall supply in the Americas is flat, with an improvement in operating rates for South America helping to offset a reduction in North American production due to operating upsets at Celanese/Mitsui and OCI Beaumont. Trinidad and Venezuela's plants are operating at 85% of nameplate capacity, and Methanex's Chilean unit around 50%; as the southern hemisphere moves into its spring months, gas availability should be steady as the residential heating load decreases. Methanex has also secured additional gas supply through May 2018 that will allow them to run at rates closer to 60% going forward.

The Asian market rose in line with the very strong Chinese market. Buying sentiment for Chinese domestic product was active especially amongst traders, and domestic production declined since seasonal natural gas constraints took effect all over China. The gas constraints will impact most of the natural gas-based facilities in China, and will gradually be eliminated after January, although this will vary from region to region. Operating rates were about 52% of nameplate capacity or 66% of effective capacity. Coastal inventory continued to decline in line with the low level of import volume in 4Q 2016. The soaring methanol price was resisted by major downstream producers. Although most methanol derivatives increased market prices in the current week, they are still under great pressure from squeezed margins. The average operating rate of MTO units is at a middle to high level although major MTO producers' margins are squeezed, and the sustained increase in methanol prices is adding great pressures to MTO producers. However, most MTO producers have to keep running to guarantee the olefin downstream production.

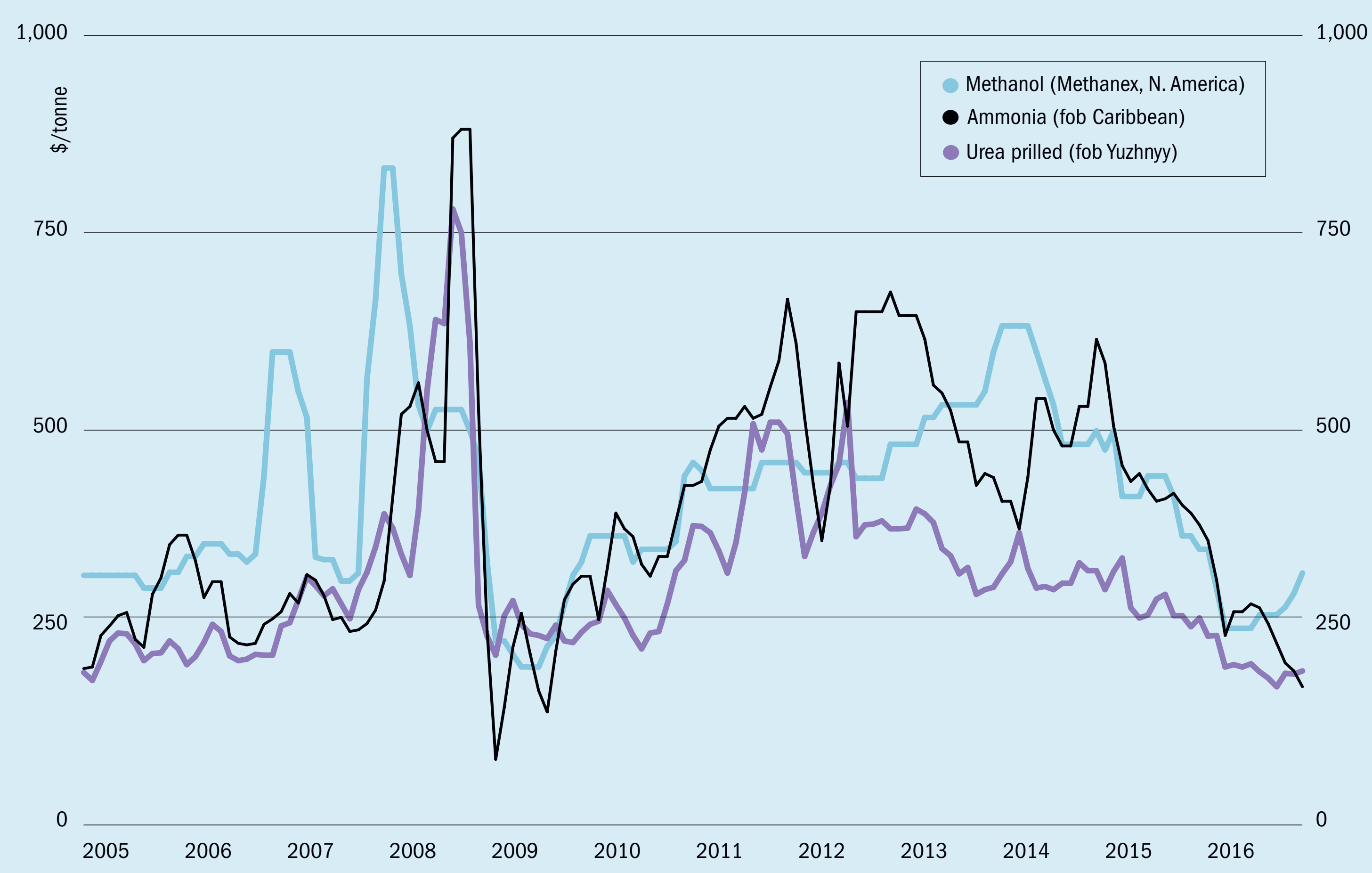
In reaction to the Chinese market, the price in the rest of Asia increased as well, and the market remains short with a limited number of firm offers. In Korea, the inventory level is very low and the spot market is tight. Domestic prices soared in line with China and major traders are under pressure to find cargoes to fulfil contracts. In Taiwan, end-user inventory remains low but is still manageable. Selling indications are tracking the c.fr China price. Buying interest from end-users is limited since they are well supplied by term contracts. In Southeast Asia, local supply recovered with the KMI and BMC units quickly returning to normal production, but, driven by the strong Chinese market, prices in Southeast Asia also increased. Asian spot prices are generally posted in the range of $310-335/t c.fr. The notional c.fr Korea price moved to above $330/t.

The European methanol market remains low on inventory but for the time being, demand is being met with supply as required. Some consumers are thought to be stockpiling inventory ahead of the higher 1Q West European Contract Price. IHS Markit expects the 1Q 2017 contract price to settle at an increase to 4Q (€248) due to lower inventories in Northwest Europe and the Mediterranean, and strong prices in China, which have led Middle Eastern producers to reallocate their inventory to Northeast Asia, where the demand, and subsequently price, has been higher. The increase in coal and natural gas prices in China have led to increased cash costs and are likely to prompt stable or increased methanol prices as a result; prices in Europe should follow this rise, in order to close any arbitrage which opens as a result. Globally the methanol market is tight and production will need to catch up. Both US contract prices rose sharply in December, up by $0.14/gallon for Methanex and $0.18/gallon for Southern Chemical; prices in Europe will need to increase from the current €248 contract price in order to stimulate a production ramp up.

In India, prices continue to rise in line with the gains made in c.fr China prices. Demand is still soft but market confidence is slowly returning following the turmoil brought by the recent demonetisation in India. Iran has restarted exports to India this month, having previously diverted material to China, where producers could sell methanol for a higher price. ■

Market outlook

Historical price trends $/tonne



Source: BCInsight

AMMONIA

- The global ammonia market experienced price increases in November due to several temporary plant shutdowns and higher gas curtailments on Trinidad.
- Firmer ammonia prices during December could lead to Russian producer, TogliattiAzot boosting its export availability to 100,000 tonnes per month, having previously reduced it due to weak margins.
- Prices will remain under pressure in January and February once short-term supply tightness is resolved, although in March, seasonal demand is likely to emerge in preparation for the spring application period in both the US and Europe.
- Spring demand is likely to bring positive sentiment to global ammonia prices although additional capacity expansions in the US and South America will contribute to the continued ammonia oversupply in the short-term at least.

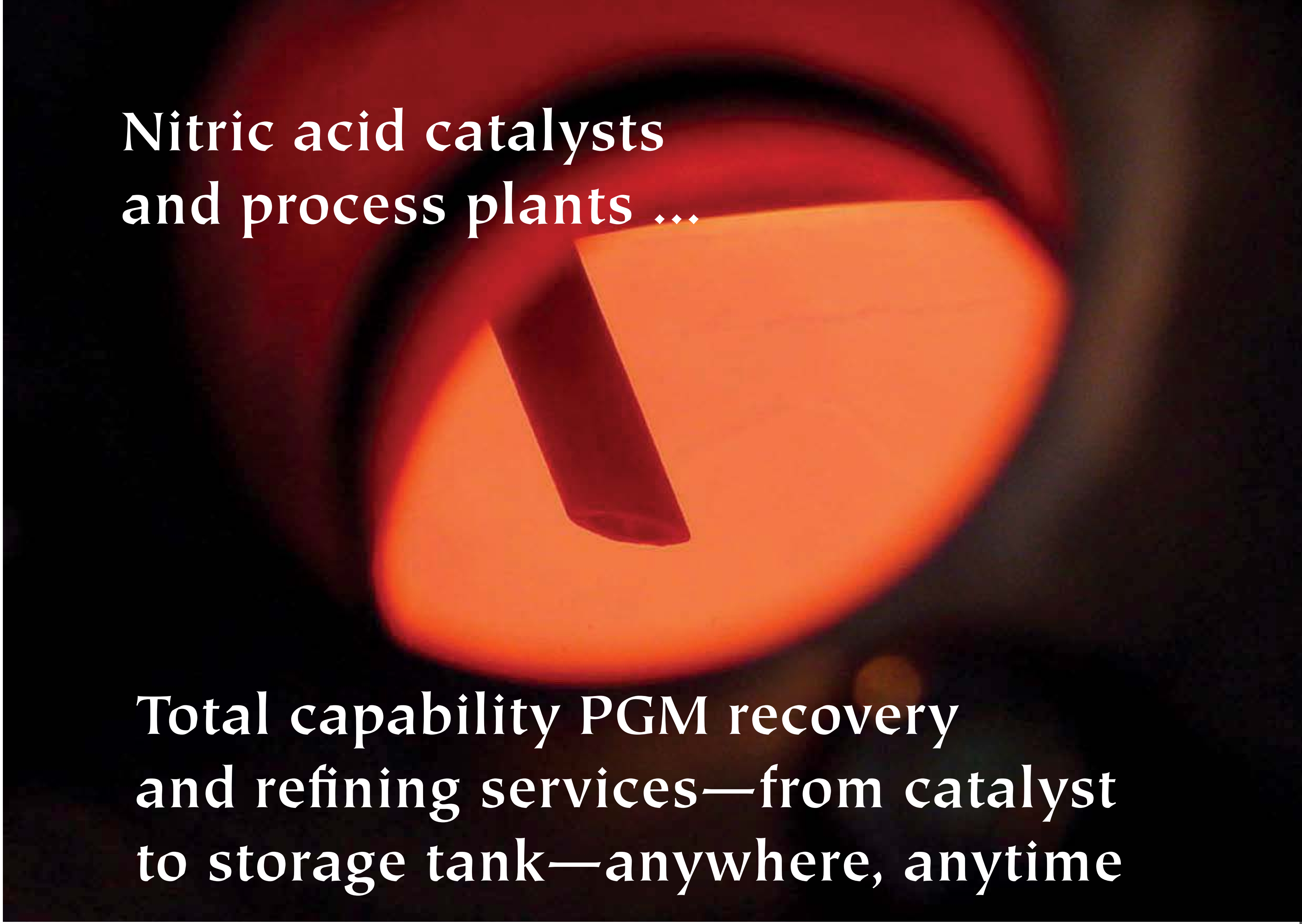
UREA

- At press time there had been no further announcement over an Indian urea import tender in December, although if this were to come to fruition it would likely absorb urea volumes and provide some upward support to prices going into the new year.
- Given the Chinese government's decision to backtrack on coal mine production limits until March 2017, the domestic coal price has the potential to fall again in RMB terms, which in turn would lower production costs to Chinese urea producers.
- Emerging seasonal demand for spring application in Europe, the US is likely to provide upward support to prices, outweighing downward pressure from capacity expansions in North America.

METHANOL

- Prices have risen sharply in China and the rest of Asia on gas curtailments which are likely to last into January, and operating upsets iat OCI Beaumont and Celanese/Mitsui in North America.
- Longer term, the first wave of new Iranian methanol plant capacity is due to come onstream in the 2017-2019, timeframe, including the Kaveh Methanol Co. facility (2.3 million t/a) in Bandar Dayyeh, as well as the Assaluyeh and Marjan Petrochemical Cos (each 1.65 million t/a). Subsequent capacity is unlikely to come onstream before 2022-2024.
- There is likely to be a staggered approach to new capacities starting up in Iran, as the government has become more cautious about "flooding" the market with methanol. Most of these new projects will supply the growing demand in China, until domestic demand increases in Iran.
- The election of Donald Trump to the US presidency could hinder US-Iranian relations, potentially making it more difficult for Iran to secure investment and technology for a large-scale methanol expansion.

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 53 54 55 56 57 58 59 60 61 62 63 64



1 47
2 48
3 49
4 50
5 51
6 52
7 53
8 54
9 55
10 56
11 57
12 58
13 59
14 60
15 61
16 62
17 63
18 64
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

Nitrogen Industry News

UNITED STATES

Air Liquide to supply technology for Grannus ammonia plant

Air Liquide Global E&C Solutions will license Lurgi technology and provide engineering services for hydrogen production at Grannus' new 250 t/d ammonia plant in Kern County, California. Air Liquide will provide oxygen-based Lurgi GasPOX technology and associated gas clean-up technologies, including a pressure swing adsorption unit (PSA) to produce high purity hydrogen for the ammonia process. It will also prepare process design packages for the gas to hydrogen process.

Grannus was formed in 2012 to develop "next generation" ammonia technology, based on partial oxidation rather than steam reforming, with associated power generation in order to generate much lower emissions levels, particularly for NOx. This will be the first commercial plant for the company, as well as the first ammonia plant to be built in California for over 60 years. The plant's 82,500 t/a output will provide 40% of California's agricultural ammonia requirements once it becomes operational in 2019. The move to smaller-scale, regional based production is hoped to allow farmers to reduce transportation costs and associated risks. The plants also have lower natural gas consumption than other modern ammonia technologies, allowing for reduced operating costs, according to Grannus.

Matthew Cox, CEO of Grannus, LLC, said "We're delighted to partner with Air Liquide Global E&C Solutions in the development and delivery of our first plant, as their leadership in industrial gas and chemical technologies coupled with their worldwide presence significantly strengthens Grannus' market entry ability."

Chad Briggs, Vice President of Sales and Technology, Air Liquide Global E&C Solutions said "We are proud to support Grannus with our leading industrial gas and hydrogen technologies for this environmentally sustainable ammonia production plant. We believe that this technology has potential in many markets worldwide."

Grannus intends to increase plant capacity designs to 'world-scale' and expand into adjacent markets including hydrogen, methanol and other downstream chemicals. ■

CF starts up Donaldsonville

CF Industries says that the new ammonia plant at the company's Donaldsonville, Louisiana nitrogen complex started-up in September 2016, and has now achieved consistent, stable operation at its nameplate capacity of approximately 3,600 t/d. At time of writing, the plant had produced 50,000 tonnes of ammonia since start-up. This is the final new plant to be commissioned as part of CF's capacity expansion at Donaldsonville, and – along with three similar sized ammonia plants in Saudi Arabia, is the largest ammonia plant by nameplate capacity in the world.

"The start-up of the new ammonia plant signals the completion of our Donaldsonville capacity expansion project," said Tony Will, president and chief executive officer, CF Industries Holdings, Inc. "With all three new plants from the expansion running consistently at or above nameplate capacities, Donaldsonville's expanded asset base and unmatched logistics capabilities are ideally positioned to serve customers in North America and around the world, while strengthening our cash generation now and into the future."

Total annual gross ammonia capacity at Donaldsonville is now 4.3 million t/a, up from 3.1 million t/a. The Donaldsonville complex has flexibility to switch production from merchant ammonia to upgraded products, and, with the commissioning and start-up of the new ammonia plant, iis now the largest nitrogen facility in the world.

Nitric acid recovery plant at munitions factory

UK defence and security company BAE Systems is building a facility to recover nitric acid for insensitive munitions at the Holston Army Ammunition Plant in Tennessee. Construction of the Insensitive Munitions Weak Nitric Acid Recovery Facility is a major part of a multi-year effort to increase the production capacity of Insensitive Munition eXplosives, or IMX, which are designed to be more stable and safer to handle than conventional munitions. Operator BAE Systems will conduct the construction under a contract worth $146.5 million. The new facility will recycle spent nitric acid that is generated at the plant and provide strong nitric acid to produce a range of IMX fills. Construction began in November 2016 and is expected to be completed in 2019.

Handover for Waggaman plant

KBR Inc. says that it has successfully completed performance tests and on October 13th officially handed over to operators Dyno Nobel the company's new ammonia plant in Waggaman, Louisiana. The plant uses KBR's Purifier ammonia technology. KBR was also EPC contractor on the project, and completed the work from contract award to handover in a record time of 42 months with no lost time incidents over the 5 million man-hours required.

"We are proud of this ground-breaking project which showcases KBR's ammonia plant technology and EPC services," said David Zelinski, KBR President of Onshore, Engineering & Construction Americas. "The completion of this project demonstrates KBR's world class project execution and customer service capabilities."

Dakota Gasification urea plant now 50% complete

The new $500 million urea plant being constructed at Dakota Gasification's Beulah, North Dakota Great Synfuels complex is now 50% complete according to local press reports. Construction work began in 2014, but three weeks of adverse weather has led to damage to the site which incurred three months of delays on the first phase of construction.

TAJIKISTAN

Chinese investment to increase urea output

The OJSC Azot/Tajik Azot nitrogen complex in Sarband has begun the second phase of its planned revamp and expansion project, which will see urea production reach 500,000 t/a. The complex was originally built under the auspices of the Soviet Union in the 1960s, and consists of 110,000 t/a of ammonia and 180,000 t/a of urea capacity in two trains. It was bought by Ukrainian fertilizer magnate Dmitry Firtash in 2002 and became part of the Group DF/Ostchem group of companies, but it was forced to cease operations in 2008 due to lack of natural gas feedstock availability. After Firtash found himself under investigation for corruption in 2014 the plant was renationalised, and since then 50% of the company has been sold to the Chinese Henan Zhongya Holding Group, which has provided $360 million for the modernisation and wholesale revamping of the complex and conversion to coal gasification. The first stage, which will take production to 320,000 t/a, began earlier this year and is expected to be completed in 2018. The second phase, which was instigated in November this year, will take production to 500,000 t/a, and is due to be completed in 2019.

TURKEY

Phase-out of fertilizer production?

Following Turkey's surprise ban of nitrate import and sale in June, which covers calcium ammonium nitrate (CAN) and potassium nitrate, as well as 'straight' AN, Turkish prime minister Binali Yildum has suggested that Turkey may phase out production of chemical fertilizers altogether to prevent them from falling into the hands of terrorists, as reported by local media. Yildrim cited agronomic as well as security reasons for the proposed switch towards more use of biological fertilizers, but it is unclear whether Yildrim is only talking about currently banned nitrate fertilizers or all mineral fertilizers, and where this would leave Turkey's considerable domestic fertilizer industry, which produces ammonia, urea, mono- and diammonium phosphate, ammonium sulphate, triple superphosphate and NPKs, as well as ammonium nitrate.

PAKISTAN

Concern over Kafco shutdown

Japan's International Corporation Agency (JICA) has expressed concern over the shutdown of of the multi-national Karnaphuli Fertiliser Company Ltd (Kafco) ammonia-urea plan at Chittagongt. The shutdown was forced by a suspension of natural gas feedstock supply to the unit, which is a joint venture between governments and private companies from Bangladesh, Japan, Denmark and the Netherlands. Kafoc was forced to close in June after the government told gas suppliers to turn off the taps. Bangladesh is chronically short of gas, and often diverts gas from fertilizer production to power stations during the summer to make up for electricity shortfalls resulting from low water levels in hydroelectric dams. Many of the country's urea plants are closed for 6 or 7 months of the year due to feedstock restrictions. However, as an international project, Kafco has generally escaped the worst of these in previous years.

In a letter to the Bangladesh government, JICA vice president Tomiyoshi said that restoration of gas supply to the plant "will not only manifest your government's commitment to further promote the 'Japan-Bangladesh Comprehensive Partnership' but also help in engendering stronger confidence among Japanese investors". However, the Minister of Power, Energy and Mineral Resources, Nasrul Hamid has replied only that the Bangladeshi government is committed to supplying gas "only if gas is available". He said that LNG imports would ameliorate the situation, but that it would be two more years before Bangladesh became able to import LNG.

UKRAINE

OPZ racks up gas debts

Ukrainian ammonia producer PJSC Odessa Port Plant (OPZ) – currently slated for privatisation – has complicated that already fraught transaction by accruing another $15 million in debts for gas payments to Naftogaz Ukrainy, taking the debt to $21 million. OPZ has so far paid for only 23% of the gas it consumed this year. Any buyer of the unit will be required to pay the company's debt to Naftogaz as part of the deal. A auction for the privatisation of the plant, with an asking price of $200 million, is scheduled for December 14th 2016. Interested parties are said to include local firms PJSC Ukrnaftoburinnia and Glenshee Holdings Ltd.

EGYPT

Foster Wheeler to supply steam reformer

Amec Foster Wheeler has been awarded a contract by the Egyptian National Company for Fertilizers and Chemicals (Agrochem) to supply materials and detailed engineering for a new steam reformer heater for its fertiliser facility in Alexandria, Egypt. The reformer, based on Foster Wheeler's Terrace WallTM design, will operate as the primary reformer for Agrochem's 250 t/d ammonia plant, based around a relocated unit. The scope of work is scheduled for completion at the end of 2016.

Jonathan Lewis, CEO of Amec Foster Wheeler said: "We have a proven track record in the design and supply of fired heaters. Our proprietary terrace wall fired heater technology is unique and proven globally and we look forward to applying it to this important facility for Agrochem."

ETHIOPIA

OCP in partnership with Ethiopian government

Morocco's state-owned phosphate company OCP has signed a $2.4 billion partnership deal with the Ethiopian Ministry of Public Enterprise, aimed at building a large-scale fertilizer plant in Ethiopia in the hopes of increasing fertilizer usage across the continent. OCP said in a press statement that "this game-changing partnership is based on a common vision between Morocco and Ethiopia for sustainable agricultural development across Africa and reinforces economic ties between the two countries." Fertilizer use in Africa is much lower than any other region of the world, but has considerable scope for increase.

OCP said that the first phase of the $2.4 billion investment will enable the production of 2.5 million tonnes of fertilizer per year through 2022, rendering Ethiopia self-sufficient in fertilizer and creating opportunities for exports. This plant, the Dire Dawa Fertilizer Complex, will produce locally mined potash and nitrogen fertilizers derived from Ethiopian natural gas, as well as consuming phosphoric acid to be supplied by OCP, "taking full advantage of both countries' complementary natural resources." The second phase of the investment, with an additional $1.3 billion, will increase total production to 3.8 million t/a by year 2025, according to the statement, allowing exports into the regional market. Tonnages for production capacities of individual components were not given.

INDIA

Technology bids in for Talcher

Bids have been received to supply the technology for the new $1.3 billion Talcher coal gasification-based ammonia-urea plant at Odisha. Shell, General Electric and ThyssenKrupp AG, as well as a fourth, unnamed company, have all reportedly submitted bids for the unit, which were invited by state-owned Projects Development India Ltd (PDIL) in September. The unit is planned to produce 1.3 million t/a of urea, considerably helping with India's growing deficit in urea production. The government has reportedly set a deadline of November 20th 2016 for selection of the technology licensor. ■

MOZAMBIQUE

Bids in for floating LNG project, possible GTL to follow

Bids have been submitted for financing of Eni's $9 billion Coral floating liquefied natural gas (FLNG) project in Mozambique, although questions have been raised about the total value of the loan given the country's ongoing attempts to restructure its $1.7 billion of commercial debt – Mozambique's national oil company has a 10% stake in the Coral project.

According to Interfax, Eni is looking for around $4 billion from project finance banks for the $5-6 billion FLNG vessel itself. Banks will be lending under the cover of guarantees from export credit agencies including China Exim, Korea Exim, Italy's SACE and France's Coface. The upstream portion of the project will be financed by the Area 4 consortium on balance sheet. Both the government and operator Eni are confident a final investment decision on the 3.3 million t/a Coral South project can be reached before the end of the year, despite Mozambique's financial crisis.

At present, the development consortium is not offering to land gas for use by Mozambique – the gas will all be exported from the FLNG tender. However, success will unlock the larger onshore Mamba LNG project, also being developed by Eni, from which Eni will give Mozambique its equivalent 'share' of the gas from Coral. Eni is also currently in discussions with ExxonMobil over selling half of Eni's 50% stake. Andarko is also developing a $20 billion, 12 million t/a onshore LNG project, with a final investment decision expected in Q4 2017, once land use issues with affected properties are resolved.

Longer term, Mozambique's government has plans to develop downstream gas-based chemical capacity in Mozambique using gas from the offshore fields, with urea, power and a 38,000 bbl/d Shell GTL plant all under development. A gas price of $2.65/MMBtu is reportedly under discussion.

WORLD

LNG is a "second revolution"

The International Energy Agency (IEA) has changed its previously cautious tone on the liquefied natural gas market, as it comes to represent an ever-larger share of gas trade. At the launch of the IEA's new World Energy Outlook, director Fatih Birol said that US shale gas had been the gas industry's first revolution, and LNG would be its second. He pointed in particular to the huge wave of new LNG capacity due on-stream from the US and Australia over the next few years, followed by Mozambique, Tanzania and Canada. This would place global LNG trade ahead of that of pipeline gas, with "serious implications" for world gas trade. The IEA is projecting LNG output to grow by 135 bcm in the next 25 years, with 55% of this coming by 2021, and subsequent expansions mainly coming from brownfield expansions. In spite of oversupply and cost overruns, the market continues to move forward, with new floating production, regasification and storage units allowing access to new markets, and pricing and contract changes. Birol said LNG would have to be priced "competitively" with coal in order to secure market share in Asia.

UNITED STATES

CB&I signs alliance agreement with Haldor Topsoe

CB&I has signed a long-term agreement with Haldor Topsoe to expand CB&I's licensing capabilities in the syngas sphere. As part of the agreement, CB&I will become a licensor for eight of Haldor Topsoe's syngas-based technologies, which complement CB&I's existing technology portfolio of more than 90 technologies and 3,500 patents. CB&I also will work with Haldor Topsoe on the engineering, procurement and construction of plants in North America.

"This strategic alliance expands CB&I's portfolio to include syngas-based technologies and gives us additional competitive offerings for the industry," said Patrick K. Mullen, CB&I's Chief Operating Officer. "We have a long history of technology collaboration with Haldor Topsoe and are confident that through our combined expertise, this new partnership will bring tremendous value to our customers."

Licensing agreement on desulphurisation technology

Casale SA has signed a global licensing and cooperation agreement with non-profit research institute RTI International which grants Casale the rights to be the exclusive sub-licensor for RTI's warm gas desulphurisation process technology for coal and other high-sulphur feedstocks. The technology enables high-sulphur gas streams, such as synthesis gas from coal or petcoke gasification, to be cleaned at elevated temperatures (250-650°C), reducing or eliminating the need for substantial gas cooling and expensive heat recovery systems. This increases overall process efficiency, reduces greenhouse gas emissions, and also reduces capital and operating costs of the entire gas clean-up block by up to 50% compared to other technologies, according to RTI. The process uses a novel transport reactor design and a high capacity, regenerable, attrition-resistant sorbent, and can achieve up to 99.9% sulphur removal from syngas at temperatures as high as 650°C and over a wide range of sulphur concentrations and operating pressures. The process was demonstrated on a 60,000 Nm^3/h synthesis gas stream in a coal/petcoke gasification plant at Tampa Electric's Polk Power Plant in Florida, where it operated successfully for more than 3,500 hours. The integration of this technology with a downstream activated-amine carbon capture process enables further reduction of total sulphur in the syngas to sub-ppmv concentrations, suitable for stringent synthesis gas applications such as chemicals, fertilizers, and fuels.

"Casale already has a strong presence in fertilizer and methanol plants based on gasification, where we are a leader in the supply of sour gas shift and synthesis technologies," said Ermanno Filippi, chief technology officer of Casale. "This agreement allows us to further expand our offering in these plants in the field of synthesis gas cleaning and conditioning, and to offer the warm gas desulphurisation process for IGCC (integrated gasification combined cycle) and other gasification-based units. This agreement builds upon a very successful long-standing relationship between Casale and RTI."

Memorandum signed for hydrogen process commercialisation

Hazer Group Ltd has signed a non-binding memorandum of understanding (MoU) with Pan American Hydrogen Inc,a Texas-based global supplier of modular hydrogen

1 47
2 48
3 49
4 50
5 51
6 52
7 53
8 54
9 55
10 56
11 57
12 58
13 59
14 60
15 61
16 62
17 63
18 64
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

generation plants, to jointly develop and commercially deploy the Hazer Process for hydrogen generation. The process enables the conversion of natural gas and similar feedstocks into hydrogen and high quality graphite, using iron ore as a process catalyst. The focus of the collaboration initially will be on small, pilot plant scale projects capable of producing 0.1 tonnes/day of hydrogen, with the scope for further development of larger-scale opportunities. The two companies will also jointly develop a technical roadmap for integration of the Hazer technology into standard hydrogen generation units as designed by Pan American.

Renewable hydrogen plant

The city of San Bernardino, California, has entered into a strategic partnership with Hydrogenics Corporation to build North America's largest 100% renewable hydrogen plant in Palm Springs. The 2.5 MW 'zero impact production' hydrogen facility will use Hydrogenics' proton exchange membrane (PEM) electrolysers to convert wind and solar energy into renewable hydrogen. Construction is set to begin in 2017, and the first phase will produce 1 tonne per day of hydrogen, allowing StratosFuel to distribute enough renewable hydrogen to refuel hundreds of fuel cell electric vehicles in southern California.

CHINA

Jilin Connell to license MTO technology

Honeywell UOP says that Jilin Connell Chemical Industry Co., Ltd. will become the ninth company to license its 'Advanced' methanol-to-olefins (MTO) process to convert domestic coal resources to ethylene and propylene, precursors for plastics manufacture. The new plant, scheduled for completion in 2017, will be located in Jilin City in Jilin Province, and will convert coal-based methanol into 300,000 t/a of ethylene and propylene. The new plant's offtake will be supplied to ethylene oxide and propylene oxide manufacturers currently operating in the same industrial park. Jilin Connell was established in November 2006 and its product portfolio currently includes aniline, nitrobenzene, nitric acid and ammonia. It also operates a 60,000 m^3/hour coal gasification unit.

Global demand for ethylene and propylene is growing 4-5% per year, with growth driven by strong demand for plastics and other chemicals, particularly in China. Honeywell UOP's Advanced MTO process combines UOP/Hydro's established MTO process with the Total/UOP Olefin Cracking Process to significantly increase yields and feedstock efficiency. At the heart of the technology are proprietary catalysts which make it possible to efficiently adjust the ratio of propylene and ethylene produced so operators can most effectively meet demand for those products.

UNITED KINGDOM

Johnson Matthey wins IChemE award

Johnson Matthey's innovative process technology for methanol production has been awarded the Outstanding Achievement in Chemical and Process Engineering Award by the Institute of Chemical Engineers (IChemE) at the IChemE Global Awards, held in Manchester on November 3rd.

The technology uses a gas heated reformer to save energy, cut costs and deliver a step change reduction in carbon dioxide emissions during methanol production and is the result of over 20 years of research. It won the category against competition from Shell and Ferrari for Industry Project of the Year at the global awards ceremony and then went on to win the overall prize of Outstanding Achievement in Chemical and Process Engineering, beating 120 entries that made the final stage of the awards.

INDONESIA

Feasibility study on methanol project

Petronas has signed a memorandum of understanding with the Sarawak State Government-owned corporation Yayasan Hartanah Bumiputera Sarawak (YHBS) to jointly conduct a pre-feasibility study for a proposed methanol plant project in Bintulu, Sarawak. The study will be conducted to assess the overall technical and commercial viability of developing a methanol and derivatives complex at the Samalaju Industrial Park, 65 km from Bintulu. Petronas is also aiming to build an ammonia-urea complex at the same site as part of the Sarawak Government's plans to transform the site into a regional petrochemical hub, and recently signed a heads of agreement with developer Huchems Fine Chemical Malaysia (Huchems) for the supply of 58 million cfd of natural gas to the nitrogen plant.

TRINIDAD & TOBAGO

Methanol production hit by gas shortages

Trinidad's methanol production reached its lowest level for two years in September according to Ministry of Energy and Energy Industries figures. Production of methanol in September was 330,000 tonnes, down 6% from August's 351,000 tonnes, and the lowest level for 2015-16. The figure was 25% down on September for the previous year, when production was 438,000 tonnes. Overall methanol production for the first three quarters of 2016 was 3.56 million tonnes, as compared to 4.07 million tonnes for 2015, a 12.5% fall. The Trinidad & Tobago Methanol Company (TTMC) train 1, with a capacity of 480,000 t/a, has been down since April, while the 580,000 t/a M4 unit did not produce during September, while the 1.9 million t/a M5000 plant was operating at less than 30% capacity for the month. Gas curtailments have been the reason for the production decline. The country's gas production actually increased by 16% in September to 3.2 billion cfd, but this is 15% down on the previous year's figure.

AUSTRALIA

Japanese-backed project for hydrogen from coal

Japan's $400 million push to run the Tokyo Olympics on hydrogen-powered vehicles has led to a Kawasaki Heavy Industries project to use Australian coal to generate hydrogen for shipment to Japan. The so-called Kawasaki Hydrogen Road aims to gasify brown coal from Victoria to produce hydrogen, which would then be shipped to Japan. The project would also feature carbon capture and storage (CCS) to deal with the carbon dioxide liberated from the process, to be pumped into depleted reservoirs in the Bass Strait. The government of the state of Victoria is said to be interested in the project as a means of using coal which will no longer be required by the Hazelwood power station in the Latrobe Valley, due for closure in March 2017.

At the moment the project is at the feasibility study stage, with Kawasaki, Iwatani, J-Power and Shell Japan working in collaboration with the governments of the state of Victorian and the Australian federal government on the front end engineering design (FEED) study.

SOUTH AFRICA

Fluor to build oxygen train at Secunda

Fluor Corp says that it has been awarded a contract by Sasol Group for the engineering, procurement and construction (EPC) of the Additional Oxygen Capacity Train project at its Secunda plant in South Africa, for an undisclosed sum. Fluor will book the contract value in the third quarter of 2016. The Additional Oxygen Capacity Train 17 project comprises the construction and commissioning of the world's largest air separation unit at the Secunda Synfuels Operations site. Fluor will provide EPC of the outside battery limits facilities for this project including the integration of Train 17's product streams with other live operations. These include high pressure oxygen, high pressure and low pressure nitrogen as well as dry air. Also included in the scope is the supply of electricity with associated infrastructure and utilities upgrades to the air separation unit.

"Fluor is bringing its proven integrated solutions approach to support this project's advancement," said Al Collins, president of Fluor's Energy & Chemicals business in Europe, Africa and Middle East. "We are leveraging our extensive knowledge of the Secunda facility and our innovative global procurement and design approaches to develop a capital-efficient solution for our client."

"This significant award will allow Fluor to demonstrate its integrated solutions approach and ability to execute lump-sum EPC projects with excellence," said Alejandro Escalona, general manager, Fluor South Africa. "The benefits to both the project and to Sasol include schedule predictability, cost certainty, reduced risk, single-point accountability, optimization of commercial process, improved interfaces and reduced cost for the owner. This award marks the continuation of a successful relationship that has spanned more than half a century and includes some of South Africa's landmark projects."

Mossel Bay to switch from gas to condensate

South African national oil company PetroSA, says that it is planning to use more heavy condensate as a feedstock at its gas-to-liquids (GTL) facility at Mossel Bay, as domestic gas resources dwindle. The switch forms part of a planned turnaround for the loss-making company, which reported a $1 billion loss for 2014-15, albeit improved to a 'mere' $30 million loss for 2015-16. Output at the GTL plant, previously known as Mossgas, fell 17% over the year to 7.9 million barrels, barely half of the site's 45,000 bbl/d capacity, as a result of continuing feedstock constraints. Production has come under extreme pressure in recent years as a result of depleting gas resources, exacerbated by the failure of an initiative known as Project Ikhwezi to replenish gas resources. The run of low oil and product prices has also been a major drain on the company's resources.

PetroSA says that it began using imported heavy condensate as a feed in 2Q 2016, enabling it to debottleneck condensate processing capacity – previously 12,000 bbl/d, but aiming to reach 18,000 bbl/d in 2016-17, and ultimately 25,000 bbl/d. The board has also approved a funding and strategic partnership strategy to enable the company to pursue strategic partners, particularly from hydrocarbon-rich countries in Africa, the Middle East, Brazil, Russia, India and China. An expression of interest has been issued for industry participants to take equity in some of the group's upstream assets.

1 47 2 48 3 49 4 50 5 51 6 52 7 53 8 54 9 55 10 56 11 57 12 58 13 59 14 60 15 61 16 62 17 63 18 64 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

People

The Fertilizer Institute (TFI) has hired **Dr Sally Flis** as its Director of Agronomy. This will be a new position which the Institute says has been created in order to support agronomic efforts related to the adoption of its 4R Nutrient Stewardship practices across the US.

"In the last six years, adoption and support for the 4R Nutrient Stewardship program has grown tremendously, and we continue to see widespread growth as growers, the fertilizer industry work to increase yields while minimising environmental impact," said Chris Jahn, TFI President. "The addition of Sally to the team gives us the needed bandwidth and experience to continue to support TFI members, growers, and other stakeholder organisations in their implementation of 4R principles in the field."

In this role, Dr Flis will provide guidance and support for 4R Nutrient Stewardship initiatives and industry efforts related to fertilizer use in the field and for directing agronomic 4R initiatives with stakeholders. This position primarily supports TFI's stewardship and sustainability programmes, but also provides guidance to TFI's government and public affairs departments regarding relevant policy, legislation, publications and outreach.

Dr Flis has more than 15 years' worth of experience working in agriculture, most recently as the feed and crop support specialist at Dairy One in Ithaca, New York, where she provided technical support for three laboratories and developed reference materials for use by animal nutritionists, agronomists and producers. Previously, she was responsible for developing 35 nutrient management plans in New York and Vermont, while also working to help plan large-scale nutrient management initiatives in Vermont. She received her Ph.D. in plant and soil science at the University of Vermont, and her dissertation focused on the effects of copper sulfate used in dairy footbaths on manure slurry ecology, soil copper fractions, and plant growth and composition. She completed her master's and bachelors' degrees at the University of Wisconsin-Madison in dairy science and agricultural sciences, respectively.

Israel Chemicals Ltd (ICL) has announced that its board of directors has appointed **Asher Grinbaum** as the company's interim CEO, effective from September 11th. Mr Grinbaum's appointment follows the resignation of **Stefan Borgas** as CEO and member of ICL's board earlier in the month. Until recently, Mr Grinbaum served as executive vice president and as the chief operating officer (COO) of the company. Mr Grinbaum will act as interim CEO until such time as a permanent CEO is appointed.

Mr Grinbaum, a resident of Israel's Negev region, has worked at ICL for over 40 years, during which time he has held a number of senior management positions. He began his employment as an engineer at ICL's Bromine Compounds unit, and since then he has held a variety of management positions, including CEO of ICL Fertilizers from 2004 to 2007, and, prior thereto, CEO of ICL Industrial Products. He holds a BA in mechanical engineering and an MBA from Ben Gurion University. ■

Calendar 2017

FEBRUARY

9-10

5th IMPCA Mississippi Conference America, NEW ORLEANS, Louisiana, USA
Contact: IMPCA,
Avenue de Tervueren 270 Tervurenlaan,
1150 Brussels, Belgium.
Tel: +32 (0) 2 741 86 83
Fax: +32 (0) 2 741 86 84
Email: info@impca.be

23-24

IFA Production and International Trade Conference, PARIS, France
Contact: IFA Conference Service
Tel: +33 1 53 93 05 00
Email: ifa@fertilizer.org

27-30

IFA Global Safety Summit, AMMAN, Jordan
Contact: IFA Conference Service
Tel: +33 1 53 93 05 00
Email: ifa@fertilizer.org

27-March 2

Ntrogen+Syngas 2017, LONDON, UK
Contact: CRU Events
Tel: +44 (0) 20 7903 2444
Fax: +44 (0) 20 7903 2172
Email: conferences@crugroup.com

APRIL

24-27

SynGas Assocititation Meeting 2017,
TULSA, Oklahoma, USA
Contact: SynGas Association
Tel: +1 225 922 5000
Web: www.syngasassociation.com

MAY

22-24

85th IFA Annual Conference,
MARRAKECH, Morocco
Contact: IFA Conference Service,
28 rue Marbeuf,
75008 Paris, France.
Tel: +33 1 53 93 05 00
Email: ifa@fertilizer.org

JUNE

29-30

International Fertiliser Society Technical Conference, LONDON, UK
Contact: International Fertiliser Society,
PO Box 12220, Colchester,
CO1 9PR, UK.
Tel: +44 1206 851819
Email: secretary@fertiliser-society.org

JULY

9-12

IMTOF 2017, LONDON, UK
Contact: Sue Appleton,
Johnson Matthey Plc,
PO Box 1, Belasis Avenue, Billingham,
Cleveland, TS23 1LB, UK
Email: sue.appleton@matthey.com

SEPTEMBER

10-14

62nd AIChE Annual Safety in Ammonia Plants and Related Facilities Symposium,
NEW YORK, USA
Contact: AIChE Customer Service
Tel: +1 800 242 4363/
+1 212 591 8100
Fax: +1 212 591 8888
Email: xpress@aiche.org

OCTOBER

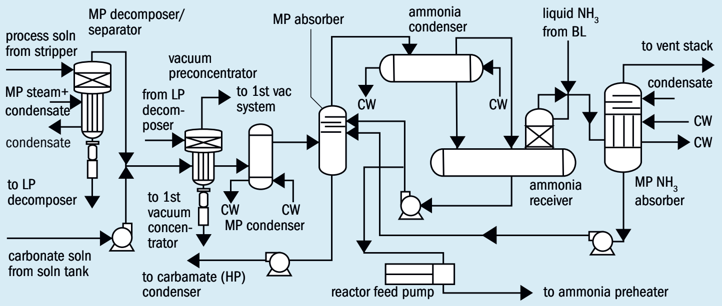
1-6

Ammonium Nitrate/Nitric Acid Conference,
AUSTIN, Texas, USA
Contact: Hans Reuvers, BASF,
Karl Hohenwarter, Borealis
Email: johannes.reuvers@basf.com
karl.hohenwarter@borealisgroup.com

Plant Manager+

Problem No. 40 Medium pressure absorber in Saipem urea plant

The function of the medium pressure (MP) absorber is to separate pure ammonia from ammonium carbamate before both of these streams are recycled to the synthesis section. Control of the process conditions of the MP absorber is one of the key control parameters in a Saipem urea plant. CO_2 carryover to the ammonia receiver is not permitted in the process as it will create corrosion problems and upset conditions in the ammonia recovery and pumping system. This round table discussion considers the problems and solutions in this process section.



Nasir Hussain from Pak Arab Fertilizers Multan, Pakistan starts the round table discussion: Please tell me about problems with the medium pressure absorber in a Saipem urea plant. What is the allowable CO_2 carryover to the ammonia receiver?

Siddharth S from TATA Chemicals ltd, India replies: High temperatures above the first tray and high levels and/or partial choking of the trays may cause CO_2 carryover from the MP absorber. If the problem persists there could also be some passing between the joints of the tray segments and inlet pipe sparger joints (gasket may be damaged). Proper sealing on the joints is a must. This may be checked during shutdown by observing the water retention period on the trays (normal retention time for water should be more than 20 minutes). During normal operation there should be no CO_2 carryover to the ammonia receiver.

Girish Prakash from TATA Chemicals Ltd., Babrala, India shares more experiences: Level fluctuations in the column during start-up/upset conditions are very common for this equipment. You need to pay attention to the actual liquid level in the column.

Mohd Saiful Mohd Sofian from PC FK, Malaysia raises a question: Has anyone implemented any improvements in this unit? There is a patented technology claiming to be able to eliminate this problem. Does anyone have any more information?

Girish Prakash from TATA Chemicals Ltd., Babrala, India explains what he has done in his plant: We have made internal improvements without any external help. If you have any particular thing in mind, please share so that we can also benefit.

Azad Panchal from GNFC, India asks a question: Can anyone tell me why the upstream temperature is kept as high as 88-90°C in the MP absorber?

Prem Baboo from National Fertilizers Ltd, India answers the questions and shares some documents: The MP absorber is the heart of the Saipem urea synthesis section. This is the vessel where pure excess ammonia is separated from ammonium carbamate. To operate at the right temperature is key for good performance of this absorber. The top temperature must be maintained at 42-43°C, while the bottom temperature is maintained at about 72-80°C. If the bottom temperature is below 70°C the ammonia will not evaporate and goes to the HP carbamate pump leading to cavitation risks. For the complete troubleshooting process refer to the UreaKnowHow.com website.

Muhammad Umar Munir from Pakarab Fertilizer, Pakistan provides more information and asks another question: The MP absorber (C-1) at our plant has a bottom temperature of ~82-84°C. The middle tray temperature is also high i.e. 60°C but the top tray temperatures are okay. I have requested the lab results and will share them with you but according to the sheet prepared by Prem Baboo, there is a probability of CO_2 carryover. The corrective action recommends checking the E-7 temperature. I carried out this check and it is running at 82°C (E-7 outlet).

My question is: What is the optimum temperature at the E-7 outlet? Also, is there any other reason that could contribute to this observation?

Prem Baboo from National Fertilizers Ltd, India replies to the question and shares a valuable document: Good question. The bottom temperature 82-84°C is not a problem – it is slightly higher than the design temperature of 75°C. It is beneficial because the higher the temperature the more ammonia is evaporated from the bottom to the top and the less recycle there is. The top temperature is OK. The 2nd tray temperature being higher is not a problem and is likely due to the fact that you have more water going to C-3 (inert washing column). This ammoniacal water is increasing the 2nd tray temperature.

The E-7 (MP condenser) process outlet design temperature is 78°C and the cooling water outlet design temperature is 66°C. E-7 is the critical equipment item, where control of sedimentation of the cooling water is important which is influenced by the opening of control valve TV 101. If the TV 101 opening is reduced there is a chance of sedimentation and scaling of phosphate/silica. In this case you must control the flow by opening TV 105.

Below are some points for your attention:

- Ensure sufficient cooling water flow in E-7, to avoid sedimentation.
- The cooling water outlet temperature of E-7 should not exceed 66°C as at higher temperatures scaling takes place.
- The inlet temperature of the cooling water to E-7 should be no less than 35°C to avoid crystallisation on the shell side (carbamate solution).

- The outlet temperature of E-7 (process) is optimum at about 78-80°C.
- The bottom temperature of C-1 should be 75-82°C.

Recently we carried out a modification to C-3 (inerts washing column): ammoniacal water was taken from E-8 (LP condenser). The following advantages were noticed:
- C-1 temperature control;
- reflux to C-1 reduced by 2 m^3/hr. i.e. reduction of recycling flow;
- LP pressure control and the total cold water flow to C-4 (LP inerts washing column) is stopped;
- V-3 (L.P carbonate solution tank) level control;
- P-7 (inerts washing ammoniacal pump) now stopped the solution transfer by deferential pressure of MP and LP;
- power saving due to stopping the motor.

Muhammad Umar Munir from Pakarab Fertilizer, Pakistan provides more figures and information: That clarifies a lot. I'll come back once I get lab results, but in the meantime I would like to show you the operating conditions from this morning:
The tray temperatures are okay so I am not expecting any carry over and the higher middle temperature is probably due to the same phenomenon as the bottom one.

Temperature, °C	Design	Operating
Bottom	70-75	82.0
Middle	45-50	55.0
Tray 1	45-50	49.0
Tray 2	40-46	45.0
Tray 3	40-45	42.0
Vapour overhead line	40-45	47.0

These are the results of the MP absorber bottom effluent: NH_3 44 wt-%, CO_2 26.7 wt-%, H_2O 29.3 wt-%.

The tray temperatures corresponding to these results are: Bottom: 86°C; Tray 1: 54°C; Tray 2: 47°C, and other temperatures are the same as given by you.

Apparently, there is an increasing trend of C-1 bottom temperatures. Moreover, the water content seems to be on the high side with relatively less ammonia. This means there is minimal chances of P-2 cavitation but what impact does a higher water content have?

Prem Baboo from National Fertilizers Ltd, India shares more information: The higher percentage of water may be due to disturbances in the common section. If your top temperature of C-1 is maintained there is no problem at all. The main sources of water for the ammonium carbonate solution tank are:
- Common section (waste water section) reflux accumulator ammonia wt-% is low: design is 35 wt-% but in practice 32-35 wt-%.
- Your LP section pressure is low resulting in water carryover to V-3 (ammonium carbonate tank), the pressure/temperature equilibrium not matching.
- Distillation tower (C-2) feed check ammonia wt-%
- Check water balance of vacuum section (i.e. steam to booster ejector)
- Cold water to C-3/E-11 (inerts washing column) is increased.
- Check also upstream.

If you have sufficient margin in TV 101 then reduce the outlet temperature to 70°C. But the inlet temperature must be watched – design is 40°C but you reduced to 35°C.

Shahbaz Soomro from FFC, Pakistan joins the discussion: What about flushing of the C1 trays? Were there no problems of C1 trays choking after this modification?

Prem Baboo from National Fertilizers Ltd, India replies: After this modification the temperature of the 3rd tray (from top) came down drastically. High temperature favours the carryover of CO_2. To date, there is no problem of choking and this modification is recommended by Saipem. In India, two plants have been implemented with this scheme.

Manikanta Vema from Kribho Fertilizers, India asks for further information: Thank you for the information about your C3/E-11 modification. I would like to know what the overall effect is on the total steam as a result of this modification apart from the power saving of the P-7 motor?

Prem Baboo from National Fertilizers Ltd, India replies: The following advantages were observed:
- Water reduced in the process by 1.0-1.5 m^3/hr.
- Reflux reduced in C-1 (MP absorber) by about 2.0-3.0 m^3/hr.
- Overall (steam to distillation, steam to LPD, etc.) LS (low pressure steam 4.0 bar) reduced 2.0-3.0 t/hr. Also LS generation in E-5 (HP carbamate condenser) increased by 1+1 =2 t/hr.
- Waste water feed reduced by 1.5 to 3.0 m^3/hr.
- KS (105 ata) reduced by 0.5 to 1.0 t/hr.

The above modification was only carried out in line-II Plant (expansion), line-I modification approval under progress.

Manikanta Vema from Kribho Fertilizers, India asks a new question: After this P-7 modification, have you faced any problems with C-1 tray temperatures, because the P-7 water helps to flush the trays to avoid partial choking?

Prem Baboo from National Fertilizers Ltd, India answers to the question: After P-7 (aqueous ammonia pump) stopped we did not experience any problems of trays choking. This ammoniacal water was taken from tray No 2 (from top). Due to absorption the temperatures of the 2nd, 3rd & 4th trays (from the top) were running higher, so the possibility of CO_2 carryover was greater than now. Due to the higher tray temperatures the reflux quantity was also higher.

This series of discussions is compiled from a selection of round table topics discussed on the UreaKnowHow.com website. UreaKnowHow.com promotes the exchange of technical information to improve the performance and safety of urea plants. A wide range of round table discussions take place in the field of process design, operations, mechanical issues, maintenance, inspection, safety, environmental concerns, and product quality for urea, ammonia, nitric acid and other fertilizers.

Southeast Asian nitrogen markets


PHOTO: PETRONAS

While nitrogen consumption in the region is relatively stable, several new ammonia-urea plants coming on-stream in Indonesia and Malaysia seem set to turn southeast Asia into a net exporter rather than importer. Longer term, however, much depends on Indonesia's gas situation, with a possible switch towards greater coal-based production.

Table 1: **ASEAN nations: statistics**

	Population, million	GDP, 2015 ($ billion)	GDP growth, 2015
Brunei	0.4	17	-0.5%
Cambodia	15.6	16	7.0%
Indonesia	257.6	861	4.8%
Laos	6.8	12	7.0%
Malaysia	30.3	296	5.0%
Myanmar	53.9	65	7.0%
Philippines	100.7	291	5.8%
Singapore	5.5	292	2.0%
Thailand	68.0	395	2.8%
Vietnam	91.7	193	6.7%
Total	**630.5**	**2,438**	

Source: United Nations, World Bank

Southeast Asia, as defined geographically by the 10 member states of the Association of South-East Asian Nations (ASEAN), can sometimes be overshadowed by the industrial giant of the Chinese economy to the north, or the growing Indian economy to the west. However, the region is nevertheless home to 631 million people at last estimate (2015). If it were a single nation, it would be the world's seventh largest economy, larger than Brazil or India, and by 2050 this figure is forecast to rise to fourth largest. Real GDP growth from 2000-2013 has averaged 5.1%; below that of India or China, but ahead of the other 'BRICs', Russia and Brazil. The slowdown in the Chinese economy has had repercussions further south, slowing ASEAN growth to an average of 4.7% in 2015 and 4.5% this year, but on the whole – while growth rates have not been as eye-catching as they were in the 1990s, prior to the regional economic crash of 1997-8 – growth has been steady and stable, especially in Indonesia, which represents 35% of the regional economy. As well as rapidly growing populations and economies, the region also has considerable natural resources in terms of oil, gas, coal and metal deposits, which has helped boost growth.

In recent years, particular attention among investors has focused on the five largest economies (apart from Singapore); those of Indonesia, Malaysia, the Philippines, Thailand, and Vietnam – what were once known as the 'Asian Tigers', and now the ASEAN-5 – where GDP growth has averaged 6.3% from 2012-2015, higher than the developing world average. It would be a mistake, however, to paint the region with too broad a brush. As Table 1 shows, there are also considerable differences between the countries of the region. Singapore is a tiny but wealthy trading hub, while even smaller but oil- and gas-rich Brunei has suffered from the collapse in world oil prices. The differences are visible even among the ASEAN-5; while Indonesia, Malaysia, the Philippines and Vietnam registered strong growth over the past few years, Thailand has been in the midst of political turmoil and those troubles have permeated its economy, leading to a sharp slowdown, and the death of King Bhumibol this year has exacerbated these concerns in spite of a recovery in the economy.

Above: Gas processing in Malaysia.

There are other potential dark clouds; economic forecasts for the region have been revised downwards due to the likely demise of the Trans-Pacific Partnership (TPP) once Donald Trump enters the White House in January 2017, and China's military encroachment on the South China Sea and its building and fortifying of artificial islands and reefs has the potential for armed clashes with other states of the region, especially Vietnam, Philippines and Malaysia.

Feedstock resources

Southeast Asia remains relatively resource rich in terms of gas and coal reserves, the former as shown in Table 2, but development of the regional gas economy has been hampered by geography – the chains of islands and mountains that have complicated pipeline building. This led to an early focus on liquefied natural gas production and export, particularly from Malaysia and Indonesia in the early days, but more recently from Brunei. It has also meant that a lot of gas reserves were not able to be connected to centres of demand, leaving them 'stranded', and consequent development of downstream ammonia and methanol production, more on which later.

Gas reserves are concentrated in two of the ASEAN countries; Malaysia and Indonesia. However, Brunei and Myanmar also have considerable reserves and

Table 2: **Gas reserves and production in Southeast Asia, 2015 (billion cubic metres)**

	Production	Exports	Reserves
Brunei	12.7	8.7	275
Indonesia	75.0	32.4	2,840
Malaysia	68.2	34.2	1,170
Myanmar	19.6	13.4	530
Papua New Guinea	9.8	9.7	140
Thailand	39.8	-	220
Vietnam	10.7	-	615

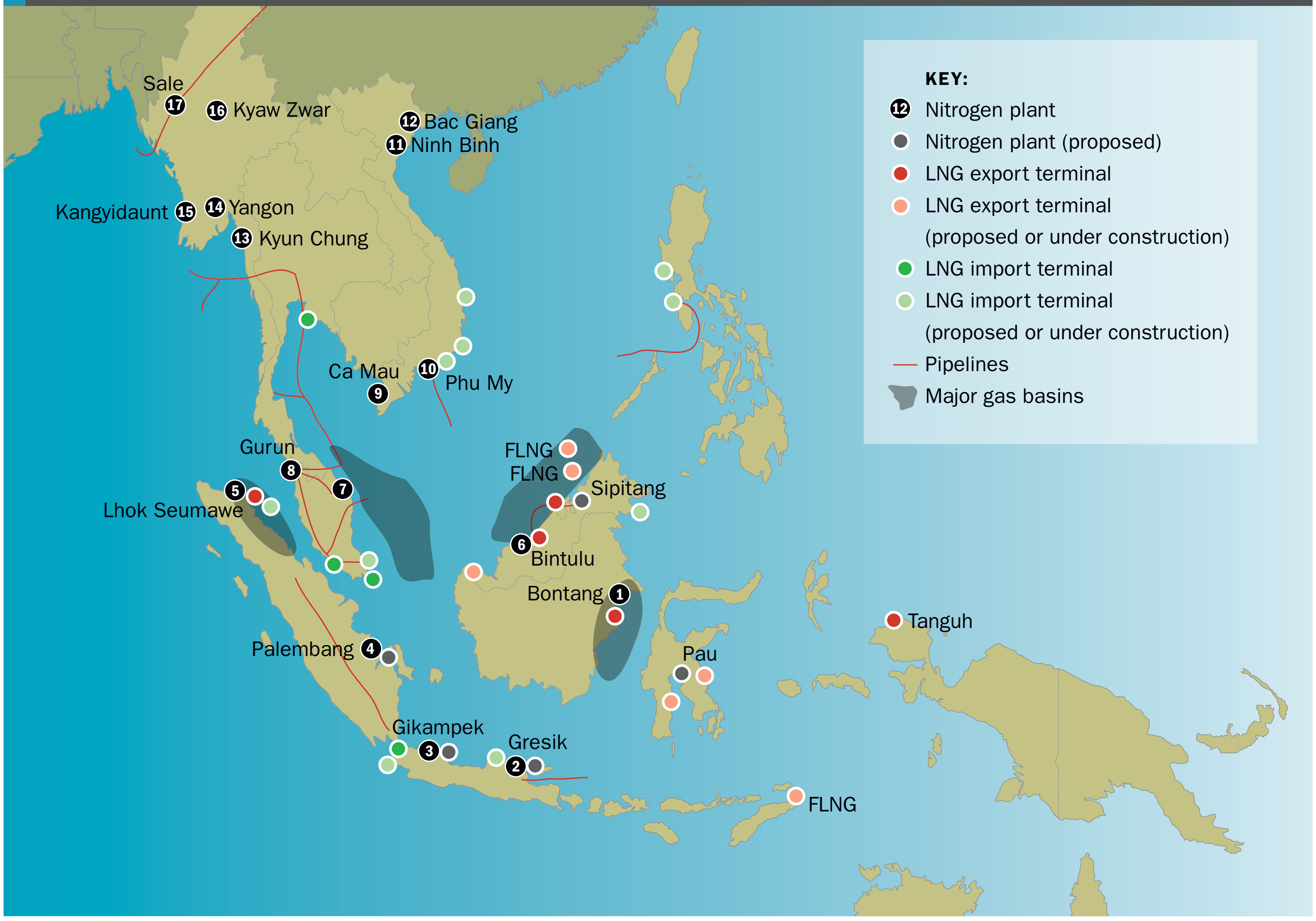
Source: BP

Table 3: **Urea production and demand, ASEAN countries, 2014, million t/a**

	Production	Consumption	Imports	Exports
Indonesia	6.8	5.8	0.1	1.1
Malaysia	1.2	0.7	0.4	0.9
Myanmar	0.2	0.2	0	0
Philippines	0	1.1	1.1	0
Thailand	0	2.2	2.2	0
Vietnam	2.2	2.2	0.2	0.2
Total	**10.4**	**12.2**	**4.0**	**2.2**

Source: IFA

Fig 1: **Southeast Asia's natural gas industries**



relatively low demand, and both countries have consequently become sizeable exporters. Thailand, Singapore and to a lesser extent the Philippines are conversely all net importers of gas, with little or no production of their own, while Vietnam produces enough gas for its own use but does not import or export any. Table 2 also shows figures for the non-ASEAN nation of Papua New Guinea, which like Brunei has relatively modest domestic needs and reserves and production in excess of this, and which is also becoming a regional gas production hub.

Figure 1 shows the development of the region's gas industry. As can be seen, the pipeline network – in spite of various regional initiatives – remains relatively underdeveloped. However, there has been considerable investment in LNG capacity, and this growth continues. Malaysia is looking to take advantage of floating LNG (FLNG) ships to access some remote offshore gas fields, while both the Philippines and Vietnam now have plans to import LNG to help meet future gas demand.

On the coal side, Indonesia is the regional giant, with massive local resources and production – Indonesia is actually the world's third largest coal producer, after China and the USA, and has edged Australia into second place as the world's largest exporter (mainly to China). Vietnam has more modest domestic production and was until recently the only ASEAN country to operate ammonia capacity based on coal. However, Indonesia, with ageing gas fields and rising domestic demand for power, is now looking more seriously at coal gasification as a supplement to its gas-based ammonia production. Japanese developer IHI started up a 50 t/d demonstrator coal to ammonia plant last year, Pupuk is converting steam generation at Kalim 5 to coal, and there are firming plans for further switches to coal down the line.

Brunei

The small Sultanate of Brunei on the northern coast of Borneo was at the forefront of gas discovery and development in the ASEAN region, with large oil and gas reserves discovered in the 1960s and LNG exports beginning in 1972 from the Lumut LNG plant. The five trains there have the capacity to produce 9.5 bcm per year, with 8.7 bcm exported in 2015, mostly to Japan and Korea under long term contracts. Brunei's oil production peaked in 1979, but gas production has been relatively constant, and well within the country's significant reserves. Apart from LNG exports, the only downstream chemical production to date has been the 850,000 t/a Brunei Methanol Company plant, which began operations in 2010, co-financed between Petroleum Brunei and Japan's Mitsubishi and Itochu.

More recently, however, Brunei has been looking to expand gas production, with an eye in further downstream developments. A sixth LNG train has been under consideration for some time, and a nitrogen fertilizer complex has been under discussion and study for over a decade, with Mitsubishi, Matsui and IncitecPivot all involved at some stage. More recently India has been considering investing in urea capacity in Brunei for export to India, trying to mirror the success of the Oman-India Fertilizer Company, and in parallel with similar discussions with Iran and various African countries. Projected capacity at present for the nitrogen plant is 2,200 t/d of ammonia and 3,900 t/d of urea (1.25 million t/a) and Brunei says it hopes to have the plant up and running by 2020, but no contracts appear to have been signed as yet.

Indonesia

The Indonesian archipelago sprawls across 5,000km of ocean, making it the world's fourth largest nation in extent, and it has a large and diverse population approaching 260 million. The country continues to develop industrially, becoming a net oil importer in 2004. Although it has the largest gas reserves in the region, gas production and consumption peaked in 2010 and have since then fallen slowly; production from 85 bcm to 75 bcm and consumption from 43 bcm to 39 bcm, although falling consumption is as much about lack of supply as lack of demand due to relatively high domestic gas prices. LNG exports have also fallen – until 2005 the country was the world's largest LNG exporter, but exports have fallen at the same time that other producers such as Qatar, Australia, Malaysia and Nigeria have overtaken it. Indonesia's mature gas fields are declining, especially the Arun field in north Sumatra, while its less developed gas fields are mainly offshore – more expensive and technically difficult to access, as well as further from end use markets – and they have struggled to attract foreign investment, especially in a lower global gas price environment. Meanwhile a lack of pipeline capacity means some associated gas is still flared. Currently Indonesia is trying to shift gas from the east of the country to the west, and has looked to LNG as a way of doing that. Even so, the government of Indonesia believes that the country will become a net gas importer some time next decade.

For that reason Indonesia has become interested in unconventional gas production, which seems to have worked so well for the US and Australia. The government is licensing shale blocks for fracking, although the industry there is in its early days so far. As noted above, the country also has huge coal reserves, mostly in the west, in Sumatra, and on the eastern side of Borneo (Kalimantan), and with it considerable volumes of coalbed methane. Indonesia's coal production has tripled over the past decade, rising from 90 million tonnes of oil equivalent in 2005 to 280 mtoe in 2014, although production dropped back last year on lower exports to China. Again, however, so far coalbed methane production has been relatively small-scale, with local and national bureaucracy slowing the pace of development. In the meantime, Indonesia has looked towards coal gasification as a chemical feedstock as a way of possibly duplicating China's success in that regard. Indonesia has enormous reserves of low-grade coal, which are largely underutilised as a result of high moisture and lower heating value content.

Indonesia's nitrogen industry is the region's largest by some way, spread across five main sites on Sumatra, Java, and on the east coast of Kalimantan (Borneo), operated by the government operates via state holding company Pupuk Indonesia. The five sites are (see Figure 1):

1. PT Pupuk Kalimantan Timur (Kaltim), established in 1977 at Bontang on the east of Borneo. Kaltim has five ammonia-urea trains with a total capacity of 3.4 million t/a of urea, most of them built in the 1980s, but the most recent of which (Kaltim IV and V) started up in 2002 and 2015 respectively. In 2014, the company was also made responsible for the 660,000 t/a Kaltim Pasifik Ammoniak (KPA) plant at the same site.
2. PT Petrokimia Gresik at East Java, built in 1972 originally using fuel oil as feedstock until gas supplies became available. Its current, replacement ammonia-urea plant, completed in 1994, has 460,000 t/a of urea capacity.

3. PT Pupuk Kujang at Cikampek in West Java. Production at the site dates back to 1975. There are two ammonia-urea trains, with a combined capacity of 1.14 million t/a of urea.
4. PT Pupuk Sriwidjaja (Pusri), the first producer in Indonesia, established in 1963 at Palembang in South Sumatra. The site has four existing trains with a combined capacity of 2.1 million t/a of urea, and a new train, Pusri IIB, began operations in August 2016. The company's newest plant has a capacity of 660,000 t/a of ammonia and 900,000 t/a of urea.
5. PT Pupuk Iskandar Muda (PIM), which began production in 1982 at Lhokseumawe near the Arun gas field in Aceh, North Sumatra, PIM has the capacity to produce 1.17m t/a of urea and 750,000 t/a of ammonia following the completion of a second plant in 2004. The PT ASEAN Aceh Fertilizer (AAF) plant was also established at Lhokseumawe in 1981 as a joint venture by ASEAN, but was idled due to lack of gas supplies, which have also affected the PIM complex.

As regards future expansion, Indonesian President Joko Widodo continues to be keen on trying to develop the country's downstream businesses in the energy and chemical sectors to strengthen Indonesia's export competitiveness. The recent Pusri expansion is one sign of this, and Petrokimia Gresik is developing a second urea plant, Amurea 2, with 660,000 t/a of ammonia and 570,000 t/a of urea capacity. Site preparation and engineering is already under way, and the new unit is due to start up in late 2017. PT Pupuk Kujang IC, provisionally scheduled for 2020, would add 660,000 t/a of ammonia and 1.15 million t/a of urea capacity.

Gas producer Surya Esa Perkasa has begun construction on a $830 million ammonia plant in central Sulawesi. The ammonia plant will be operated by Panca Amara Utama, in which Surya Esa Perkasa holds a 60% stake. Japan's Mitsubishi Corp. is a minority shareholder. The plant will be built on a 192-hectare site near a gas field jointly operated by Pertamina and energy company Medco Energi International, which will supply natural gas feedstock. Commercial operation is scheduled to begin in the fourth quarter of 2017 or early 2018. The plant will have an annual capacity of 650,000 t/a. PAU plans to sell the ammonia in both the domestic market and elsewhere in Asia.

PHOTO: PETRONAS

Construction of the SAMUR urea plant, Malaysia.

As previously mentioned, Japanese engineering giant IHI Corp has begun operations at a pilot coal to ammonia plant, co-located with state-owned fertilizer producer PT Pupuk Kujang. It converts 50 t/d of low-grade coal to make ammonia fertilizer. The project is funded by Japan's Ministry of Economy, Trade and Industry (METI) and runs under cooperation with some Indonesian ministries with IHI as the executor and PT Pupuk Kujang as the local host. Longer term, IHI is looking towards a commercial-scale, 1,000 t/d ammonia plant.

PT Pupuk Sriwijaya Palembang (Pusri), is carrying out a feasibility study jointly with state-owned coal miner PT Bukit Asam to build a coal gasification plant in South Sumatra, with a projected 1,500 t/d of ammonia and 2,600 t/d of urea capacity, and another study is being conducted in East Kalimantan where coal reserves are abundant.

Malaysia

As Table 2 shows, Malaysia also has very large natural gas reserves; more than 1 trillion cubic metres, but with a population only one eighth of Indonesia's, domestic energy demand is correspondingly lower and gas available for LNG export and downstream chemical production is correspondingly larger. Malaysia has three currently existing nitrogen facilities. The first is a development by ASEAN in similar fashion to the ASEAN Aceh plant in Indonesia. Located at Bintulu on the northwest coast of Borneo, ASEAN Bintulu has 400,000 t/a of ammonia and 540,000 t/a of urea capacity.

State producer Petronas operates two facilities. The first, built in 1999, is an ammonia-facility at Gurun, Kedah, with 595,000 t/a of urea capacity. The other, completed in 2002, is a 450,000 t/a stand-alone ammonia plant at Kerteh in Terengganu province.

Like Indonesia, Malaysia continues to develop domestic nitrogen capacity. Petronas broke ground on its new Sabah Ammonia Urea (SAMUR) project in February 2012, and it is due to be completed by the end of 2016. The $1.5 billion SAMUR project includes a 740,000 t/a ammonia and 1.2 million t/a urea project at the Sipitang Oil & Gas Industrial Park in Sabah. Haldor Topsoe is providing ammonia technology and Saipem urea technology, with Uhde Fertilizer Technology licensing granulation technology. Mitsubishi Heavy Industries have the EPC contract.

Myanmar

Myanmar's development had been held back by long years of isolation and international sanctions imposed upon the military-backed government after it annulled elections in 1990 and imprisoned the National League for Democracy (NLD) leader Aung San Suu Kyi. However, from 2008 Myanmar began a transition back to democratic government culminating in the freeing of Aung San Suu Kyi and the NLD winning parliamentary representation in the 2012 by-elections and winning the 2015 national election and forming a government. The lifting of international sanctions has led to an influx of badly-needed foreign investment into Myanmar, and GDP growth has averaged 7% for the past few years. Natural gas production has increased rapidly, from 12.7 bcm in 2012 to 19.6 bcm in 2015. Woodside Petroleum, drilling offshore earlier in the year, said that it had revised upwards its estimates of gas in the basin there. The country's current natural gas output mostly (ca 70%) comes from the offshore Yadana and Yetagun fields, with a pipeline running from them via Yangon to Thailand.

The sanctions years have left Myanmar with many infrastructural challenges. Its five ammonia-urea plants have a notional total capacity of around 650,000 t/a; 66,000 t/a at Sale and Kyung Chaung, 200,000 t/a at Kyaw Zwa, and 165,000 t/a each at Myaung Daga and Kan Gyi Dauk. However, Kyung Chaung and Kyaw Zwa have been closed down for some years, while the others have operated at drastically reduced capacities due to gas shortages and maintenance issues, and total output was rarely more than a couple of hundred thousand tonnes, with Chinese imports making up most of the country's demand. The country's fertilizer application rates are at very low levels compared to the rest of the region, and there is plenty of scope for expanding both domestic consumption and production, the latter via domestic gas. There were abortive attempts around the time of the Yadana gas project in 2002 to piggy-back new ammonia and urea capacity onto the development, but this eventually fell by the wayside. The lifting of sanctions has been seen as a renewed opportunity for Myanmar to develop more of a domestic fertilizer industry, but so far, aside from a plan to revamp the shuttered Kyaw Zwa plant, nothing concrete has emerged, while neighbouring Bangladesh has suggested importing Myanmar gas to run its own gas-starved urea plants.

Vietnam

Vietnam has four nitrogen-producing plants. There are two older, Soviet-era coal gasification-based ammonia-urea plants in the north of the country, at Ninh Binh and Bac Giang (Ha Bac). In the south there are two gas-based plants using gas from the Nam Con Son basin, developed by BP, PetroVietnam and Conoco, which comes ashore at Phu My, where a fertilizer and power plant complex was built from 2001-2004. A second, identical plant was completed further south at Ca Mau in 2012. Both have a capacity of 740,000 t/a. While the gas-based plants generally operate well, however, the two coal-based plants have been plagued by production problems, and are reported to be in serious financial difficulties resulting from overhanging loans and adverse movements in coal and urea markets. Ha Bac, owned by state producer Hanichemco (Ha Bac Nitrogenous Fertilizer and Chemical Co Ltd) spent $570 million from 2010-2015 in upgrading and expanding the plant from 180,000 t/a to 500,000 t/a of urea output. However, it is reported to have lost $30 million in 2015 and is on course to lose another $22 million this year. Meanwhile Ninh Binh, owned by Vinachem (Vietnam National Chemical Co), was built from 2008-2012 at a cost of $670 million, including $250 million in Chinese loans, and has a nameplate capacity of 560,000 t/a. The company has been paying 4% interest on the loans, higher than a usual commercially available rate, but moreover has faced coal price rises from $35/t to $90/t at the same time that global urea prices have sunk from $600/t to $250/t. The plant was forced to close in May 2016 after losing money for all four years of operation, with total losses now amounting to $120 million. The local government is now appealing to Vietnam's central government to approve a rescue package for the beleaguered plant.

On paper, Vietnam has overbuilt urea capacity, reaching a potential output of 2.65 million t/a from its four plants against domestic demand of 2 million t/a, aiming to export the rest. However, the production and financial issues at the coal-based urea plants and the current oversupplied global urea markets have made exporting difficult, and in practice the country just about breaks even.

Regional supply/demand balance

Almost all of the nitrogen production in the region is based on urea, apart from some ammonium sulphate and nitrate production in Indonesia. Table 3 gives a breakdown of urea production and consumption across Southeast Asia, listing the major producers and consumers are listed - volumes consumed by Cambodia, Laos, Brunei, Singapore and New Guinea are less than 50,000 t/a each. Indonesia, and to a lesser extent Malaysia and Vietnam are the major producers, and of those, only Indonesia and Malaysia are major exporters. Vietnam, although it technically has a surplus of urea production, has remained a slight net importer in recent years because of domestic costs of production and the production and financial issues noted above with its coal-based plants.

Indonesia is also far and away the largest consumer, consuming almost half of regional urea demand, with Thailand and Vietnam the other most significant users of urea, and Malaysia and Philippines more moderate consumers. As non-producers, Thailand and Philippines must of course source all of their urea from imports. Although there is intra-regional trade, with Indonesia supplying to Vietnam, for example, it can also be seen that the region as a whole was a net importer of urea in 2014, with most imports coming from China, and to a lesser extent the Middle East.

These patterns have changed over the past decade. Vietnam was a major importer of urea until about 2012, when the new Ca Mau plant and the expansions at Ha Bac were able to substitute for imports. While Malaysian exports have remained relatively constant over the past 10 years at around 800-900,000 t/a, Indonesia, once a major exporter, went through a period around 2006 when exports were restricted. Some of this was down to gas shortages, with falling gas production leading to less gas available domestically as long-term LNG export contracts required the LNG to be exported. As these contracts have lapsed, so Indonesia has been able to redirect gas towards domestic urea production.

Looking forward

Nitrogen consumption in the region in the major consuming nations is relatively mature and unlikely to increase dramatically, but there is still scope for future growth in Myanmar, Laos and Cambodia. However, growth in regional demand is likely to be relatively modest, and certainly outweighed by growth in regional production. New capacity has started up in Indonesia at Kaltim V (although this replaced the old Kaltim I plant) and Pusri IIB last year and this, and the SAMUR plant in Malaysia is also due for start-up soon. These three between them represent a net increase of 2.7 million t/a of urea capacity, more than enough to take up the net regional deficit, and possibly pushing it slightly into surplus. And there are more plants planned at PAU in Indonesia and potentially Pusri. While there is also the potential for new capacity in Brunei, Myanmar and Papua New Guinea, however, the current low price regime in the urea market and oversupply from China makes this far more marginal in the short term. This is also true of the potential for urea exports from the region, which again will be dependent on prevailing international prices.

Likewise the gas situation in Indonesia remains an imponderable – having crimped output in the past, and possibly doing so in the future. It could be – further down the line – that some plants are forced to switch to coal as a feedstock and others operate more seasonally as gas is available, as happens in countries like Bangladesh and Pakistan. ■

Asset management for steam reformers

Thomas Fortinberry, AMETEK Land Business Development Manager – Industrial Gas, discusses fixed thermal imaging for steam methane reformers and how improved access to process temperature data can optimise efficiency, reduce downtime and extend asset life.

Steam methane reforming of natural gas is one of the most commonly used thermal methods for hydrogen generation. For example, natural gas reforming accounts for 95% of the hydrogen produced in the United States. Growing worldwide demand for hydrogen has driven the increased use of steam reformers, backed by the desire to make the process as productive as possible. There is a simultaneous movement to enhance the inspection and diagnostics used in the creation of hydrogen, methane, ammonia and other gases, driven by many factors, including an increased focus on safety for operators, reduction of downtime and cost efficiency.

As part of the process, widely available and relatively inexpensive methane and water are reacted in the presence of a catalytic converter. During the production process, natural gas is combined with steam and heated at high temperatures (700–1,000°C) under pressure in the presence of a catalyst. The result is carbon monoxide, hydrogen and a small amount of carbon dioxide. In the next step, carbon monoxide from the reforming reaction interacts with steam, again using a catalyst, to produce additional hydrogen. Finally, carbon dioxide is removed, leaving pure hydrogen. Throughout the process, the heat resulting from the combustion of fuel gas from burners in the furnace box is transferred to catalyst tubes by radiation.

Steam reformers used in hydrogen, ammonia and methanol plants are complex, energy intensive and expensive. The monitoring of tube wall temperatures (TWT) can help optimise catalyst tube life and ensure longevity, energy efficiency and productivity. As tubular steam reformers can be either top-fired or bottom-fired, catalyst tubes are arranged in parallel rows with burners between the rows at the top or bottom of a furnace box that is heated from 1,000–1,100°C. Alternatively, tubes can be arranged in single rows between opposing furnace walls in side-fired and terrace-wall-fired reformers. The reaction occurs through the tubes at 900°C, exiting the bottom. There are established TWT upper limits based on the design of the tube and the interior of the fire box, at which temperatures the tubes begin to expand.

Industry challenges

The most frequent challenges that plant operators face are issues with the burner, flue gas distribution and the catalyst. All of these can directly affect TWT and lead to premature tube failure. To prevent failures, most operators tend to be overly cautious on TWT, and a plant can thereby lose valuable production output every year – a 10°C drop in temperature can result in 1% decrease in productivity. Even taking a cautious approach, tube failures can still occur, due to hot spots on tubes and hot areas within the convection box, so even producers running at a reduced rate still are not guaranteed to have a balanced, reliable reformer. Reformer tube failure and process flow problems result when temperatures are too high. Even at temperatures only 20°C above the design temperature, a tube's lifetime may be cut in half. Maintaining optimum temperatures therefore is critical.

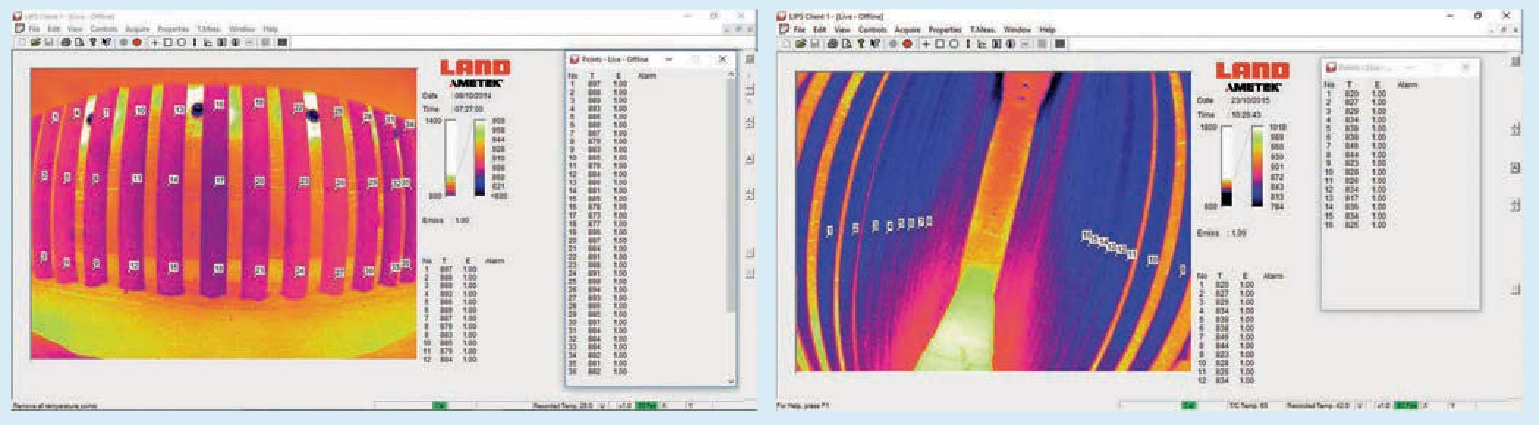
The challenges inherent in a steam reformer environment range from the basic difficulty of obtaining TWT right through to the catastrophic failure of tubes. Adding to that difficulty is the extremely harsh environments in which flue gas at the outer surface of reformer tubes is around 960°C and inner-surface process gas ranges from 450°C to 900°C. Temperature-related issues with reformers include creep damage, stress cracking, extrusion rupture and overheating. A thermal gradient through the tube wall is more significant at the bottom or close to the bottom of the tube, causing differential creep strain, which is a primary cause of damage. A fifth of all incidents involve tube cracking. Human error, however, is the main reason for catastrophic failure.

Operators are required to have an in-depth understanding of a reformer's behaviour. They also must be able to analyse data and make rapid decisions when faced with catastrophic failure. Significant operator experience is necessary to fully understand basic reformer construction, process flow, heat transfer principles, background radiation, and emissivity along with the cooling effects that occur when the peep door is opened. Regular opening of the peep doors can result in increased stress on the tubes and potential cooling of the tubes up to 30°C directly in front of the peep door. With that in mind, operators need data on the TWT that is accurate, repeatable and reliable.

Asset management is critical. That means having an effective method of temperature measurement. Reformer tubes are highly valuable assets, so extending tube life is essential. By continually monitoring readings, the operator will get an early warning of increasing tube wall temperatures, which can then be used to counteract potential catastrophic failure. Continuous monitoring, likewise, will allow the operator to safely and confidently increase temperatures, with a view toward increasing production.

1 47
2 48
3 49
4 50
5 51
6 52
7 53
8 54
9 55
10 56
11 57
12 58
13 59
14 60
15 61
16 62
17 63
18 64
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

Figs 1 & 2: **Thermal view inside and reformer tube furnace with data points**



Measurement methods

What is clear is that to meet the demands for greater production, efficiency and safety, continuous 24/7 monitoring is required. Whilst several different temperature measurement methods are available, the most effective are:

- Hand-held spot pyrometers that enable routine spot measurements to be taken. Pyrometers are highly accurate and are considered an industry standard for measuring tube wall temperature. They can be used to optimise steam reformers by maintaining operation closer to design temperatures and, in many situations, can provide adequate accuracy. However, with pyrometers, the operators are only able to view a local spot on the tubes and may miss hot spots in other locations.
- Fixed thermal imaging provides more accurate and repeatable results than hand held pyrometers as they are less liable to human error and enable optimisation of the TWT to ensure a long tube life. Here, thermal imaging cameras are inserted into the reformer, with the end of the imager ¼" from the inside reformer wall refractory. Imagers are water- and air-cooled to ensure accuracy in the hot atmosphere of the reformer. This method improves efficiency and minimizes the risk of catastrophic failure.

Fixed thermal imagers

Accurate temperature measurement must take emissivity into account. Within the reformer environment, several objects can reflect off the surface. Hand-held pyrometers and visual inspection can wrongly interpret the reflections as real data, causing errors in temperature measurement. Thermal imaging cameras, such as the hazardous area certified NIR-B 3XR borescope from AMETEK Land, which are mounted strategically within the reformer, do not allow this to happen. The fixed thermal imager delivers a high-resolution image, with accurate real-time measurements of both the tube skin and refractory surface (see Figure 1).

The image, combined with the 90° angle field of view, allows for multiple parallel tubes to be measured simultaneously. This can dramatically enhance efficiency and safety as well as provide for better asset management and furnace optimisation (Figure 2).

With the NIR-B 3XR, hot and cold areas within the furnace are easily identified and uneven heating becomes visible in real time. Burners operating incorrectly can be identified along with the effects of impinging flames. The use of a short wavelength minimises errors associated with varying emissivity so that highly accurate temperature measurement data can be taken, stored and fully analysed over the lifetime of the reformer. Use of fixed thermal images also allows the plant to monitor temperature during start-ups and shutdowns to optimise efficiency and reduce energy usage.

One of the major benefits of using fixed thermal imagers like the NIR-B 3XR is their rapid response time. Using the Land Image Processing Software (LIPS) provided with the imager, for example, the software will sound an alarm the moment the tube wall reaches the maximum temperature in any region, identifying the problem region and allowing the operator to take corrective measures to fix the issue. Fixed thermal images collect a huge amount of data that then can be used to create TWT trending charts to identify problem areas that can be corrected during operation or repaired during a planned shutdown. Data capture also is useful for conducting remaining life assessments on tubes or to help plan for tube replacement during maintenance work. There is also an option for alarms for use in control and automation as well as a playback facility of any pre-alarm event.

Summary

The growth in the demand for hydrogen looks likely to continue and along with that, the pressure on hydrogen production plants to increase production while improving safety, controlling costs and reducing downtimes. As means of improving production efficiency and reducing maintenance and repair costs, there has been increased interest in the use of fixed thermal imaging cameras for continuous and improved temperature measurement of the steam methane reformer tubes. Asset management is an essential part of why this continuous temperature monitoring is so important. By operating the process over temperature drastically reduces the lifespan and, therefore, increases operating costs. Similarly, the proper management of temperatures during start-ups, operation and shutdowns has proven to extend both tube and catalyst life with less downtime and fewer unplanned tube replacements.

Fixed thermal imaging is a major new development in temperature measurement for industrial gas applications that has helped optimise efficiency and significantly improved process temperature monitoring. Use of the NIR-B 3XR borescope, as example, has led to increased productivity, greater asset protection and enhanced tube life. It also has reduced risks to operators, who no longer need to be in hazardous areas to conduct temperature measurements on a regular basis.

Fixed thermal imaging goes a long way to enabling plants to meet the challenges they face with steam methane reforming, by providing accurate, rapid response data that helps them to optimise efficiency and maximise production.

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 53 54 55 56 57 58 59 60 61 62 63 64

Old meets new in Venice

Casale's fourth customer symposium, dubbed 'Innovation Meets Experience', brought delegates to the beautiful city of Venice in October to look at where the syngas-based chemical industry might be heading over the next decade.

Casale symposia only come around once every five years, so while thus year's was only the fourth, the first one was held back in 2001. Welcoming delegates to Venice, Casale's president Umberto Zardi said that this year would have three times the participation of the first one, with over 20 different nations represented. And just because the industry's technologies are mature, he said, it doesn't mean there is no need for new developments. The world continues to face challenges, such as coping with an increased population without damaging the environment, which only the nitrogen industry can help solve. He also noted that revamping can dramatically improve the efficiency of ammonia production, with the revamps that Casale had carried out only in the last five years already being responsible for reducing CO_2 emissions by more than 1 million t/a.

Casale's history is not as long as Venice's, noted CEO Giuseppi Guerino, but 95 years is still a long time in chemical industry terms, going back to Luigi Casale's first ammonia plant design in 1921. Casale was the first company to license an ammonia plant design, and the company's more recent move back into complete plant sales and now the acquisition of technologies across the nitrogen spectrum – nitric acid, ammonium nitrate and melamine – means it is able to find synergies and optimise an entire complex, not just individual process units. Its most recent tie-up is an agreement with Black & Veatch on licensing and constructing Casale plants.

Chief operating officer Federico Zardi reviewed the group's capabilities and achievements. Over the last 30 years, it has carried out 437 revamps, 262 ammonia, 151 urea and 22 methanol, and now two nitrate plants. It has also built 95 new plants, including 62 ammonia (22 in the last five years – mainly in China), 4 urea, 24 methanol, 2 melamine and 3 nitric acid. Its latest award has been for an integrated complex, including 1,000 t/d of ammonia, 1,700 t/d of urea and 40,000 t/a of melamine capacity.

The next ten years

Chief technology officer Ermano Filippi tried some crystal ball gazing, looking at several emerging technologies which have the potential to be 'disruptive' to the direction of the fertilizer industry, even in such a relatively mature field. He suggested that world-scale plants were likely to continue moving to larger plant sizes, but that there was also scope for small, modular plants to take advantage of flared gas or unconventional feedstocks. Plants were likely, he said, to become more efficient, more reliable, with more automation and lower emissions.

How big can plants go? The largest methanol plant in the world today is 7,000 t/d, based around autothermal reforming. In future this could reach 10,000 t/d using existing technology for plants aimed at methanol to olefins or fuels production, using a high pressure autothermal reformer. On the ammonia side the largest plant is currently 3,300 t/d, and most use steam reforming, but using a front end similar to a modern methanol plant this could be taken to 6,000 t/d, and using a high pressure reformer could be even larger, as this reduces duty on the syngas compressor, which is the key process bottleneck.

Reducing plant sizes to, eg 10s of tonnes per day (equivalent to the size of a single gas well) would require a different reforming technology, and Casale is looking at a partial oxidation reactor using a modified truck engine using an air/methane feed mix. The aim is to reduce the expense of a similar sized reformer by up to 90%.

Other new technologies which he said could affect the industry included quantum mechanical computer simulations which can now simulate detailed reactions on catalysts, leading to optimised catalysts and process conditions and reduced by-product formation; 3D printing in metal, allowing the production of more complicated parts such as burner tips and on-demand replacements with shorter delivery times; developments in IT allowing the modelling of process control and on-line optimisation of plants – the 'internet of things' may soon apply to real-time data gathering from sensors and 'big data' analysis of plant operations, and remote plant monitoring, perhaps by the licensor of the plant to assess condition and performance.

Legally, CO_2 emissions are likely to be more regulated and taxed in the wake of the COP21 agreement in Paris. Most emissions come from the primary reformer stack, and capturing is possible but expensive in capex/opex terms. Casale are looking at a new process for lower cost carbon capture using solid sorbents and temperature swing absorption (TSA) as opposed to the pressure swing absorption (PSA) used in hydrogen plants. Regeneration uses heat removed from process gas. The process is moving to a pilot plant stage in 2017-18.

Carbon footprint

Yara's Danny Franceus considered the future of carbon pricing. There are arguments for exempting fertilizers from this – fertilizers are needed for food security, as arable land is relatively limited compared to population growth, and the emissions from fertilizer production represent only a fraction of the impact from agriculture – CO_2 released by deforestation worldwide for example is more than the total emissions from Europe. More efficient fertilizer application could therefore lead to less deforestation and hence lower CO_2 emissions. Nevertheless, current legislation, regulations, best available techniques (BAT) etc all focus on production. Fertilizers Europe reckons the BAT for ammonia production should emit less than 3.6 tonnes CO_2 per tonne N. Figures can be misleading, though. For example, urea (as it consumes CO_2 in production) emits less CO_2 than calcium ammonium nitrate (CAN), but when losses in application are also taken into account, CAN is better overall.

Market papers

The first day of the conference concluded with a session looking at the markets for syngas-based products.

Nitrogen+Syngas editor Richard Hands began with an overview of feedstock markets, highlighting how the industry's preferred feedstock had swung from coal to gas in the 1960s, moving to cheap gas locations like the Middle East, then flirted with coal and other heavy feedstocks once again during the early 2000s as gas became a victim of its own success and so-called 'stranded' gas began to disappear, and now has swung back to gas as coal becomes regarded as environmentally unacceptable and shale gas and the spread of LNG continues to transform the gas market. But availability is now as crucial as pricing, and in places like China, India, Vietnam and Indonesia, and even parts of the US, the era of coal is not yet dead, while new greener feedstocks are encouraging the development of smaller scale, more modular plants to exploit them.

CRU analyst Alistair Wallace gave an overview of the US nitrogen market. The US is the third largest N consumer in the world, with urea and UAN both accounting for about one third of application each. Notably, the intensity of N application per hectare is lower in the US than Europe, but still slowly increasing. Meanwhile, use of industrial grade AN has declined with falling coal production. Around 8 million t/a of US nitrogen capacity moved offshore from 1998-2008 due to high gas prices, but this has rebounded on the shale gas boom, boosting US production by 6 million t/a. Cheap gas and low cost capital made the US market very attractive, with 33 expansions announced with a total of 17.5 million tonnes ammonia equivalent. However, of these, only 15, with around 5.6 million t/a of ammonia equivalent are likely to complete, including only one major greenfield site – the Iowa Fertilizer Co at Wever. Capital costs have risen of the long term, while falling phosphate production has reduced demand for ammonia. The investment cycle is essentially over, Alistair concluded – US capacity will peak by around 2018, and which time North America will still be importing around 1 million t/a of nitrogen in 2020.

Mike Nash of IHS summarised the methanol market. Rising operating rates over the next 2-3 years depend very much on the success of methanol to olefins (MTO) production in China – MTO capacities continue to rise rapidly – although there are potential game changers in the longer term horizon, including the wider use of methanol as a shipping fuel to get around International Maritime Organisation low sulphur fuel rules, and increased blending into gasoline. The US is likely to become a net exporter of methanol over the 2016-21 time horizon, with Chinese imports increasing.

H Buschner of Borealis gave a brief overview of the melamine market. It is a small scale, niche production, with total production of 1.4 million t/a in 2015, but growth is stable and robust at around 3-4% year on year. It is strongly linked to GDP growth and construction industries, and needless to say China has become the driving force in the market, although Europe still remains the largest consumer for now. Chinese capacity overtook Europe in around 2010, but as in so many other industries China has overbuilt capacity, and operating rates have fallen to below 50%.

Technologies for new fertilizer plants

Casale's Rafaelle Ostuni gave a run-down of how Casale sees its current offering for the construction of new fertilizer plants. Casale expects a growing demand for new plants in the following main categories:

- medium-scale ammonia plants to replace purchased ammonia for local use (e.g. in nitrates and phosphates facilities).
- world-scale plants serving regional urea markets, based on gas or coal.
- large-scale plants for centralized production at gas hubs, producing urea for export in the global market.

Delegates in the historic ballroom of the Monaco & Grand Canal Hotel.

To fulfil these demands, Casale is offering several basic plant designs. Its A600 concept is for 'medium-scale' (around 600 t/d or 200,000 t/a) gas-based ammonia plants, where the constructor is looking to replace imported ammonia with domestic production, and the focus is on lowering capital cost by simplifying the flowsheet rather than achieving economies of scale. Rather than using both a high temperature and low temperature shift, there is a single medium temperature shift (MTS) converter downstream of an autothermal reformer, with a pressure swing absorption section between the MTS and synthesis loop to avoid the steam reformer and solvent-based CO_2 removal section. The ammonia synloop operates at moderate pressure to ease duty on the syngas compressor. Capital costs are 30% lower per major equipment item and 20% lower overall, with additional possibilities for modular construction.

Next up is the A3000 concept, based on large-scale (2-3,000 t/d) ammonia production, where the focus is on the energy efficiency of production, achieving 6.4 Gcal/t ammonia as compared to the 7.5 Gcal/t typical of the A300. It does this by running the steam reformer at 60 bar and incorporating a stoichiometric air feed to the secondary reformer. This lowers compressor duty by 10% and allows use of a single body syngas compressor with lower power consumption.

Finally, the A6000 concept is designed to achieve maximum economies of scale at up to 6,000 t/d, reducing capital cost per installed tonne by 25-30% and using a pre-reformer, steam reformer and oxygen-fed autothermal reformer similar to the front end of a large-scale methanol plant. The nitrogen from the air separation unit is then fed directly to the ammonia synthesis section. Syngas purification removes all inerts with a cryogenic liquid nitrogen wash.

A2000C is a variant for coal-based ammonia plants using the innovative Warm Desulphurisation Process licensed from RTI (see Industry News, this issue) as part of syngas cleanup.

For urea, Casale are offering the adiabatic stripping reactor (ASR) – a split flow reactor, the top of which is a urea synthesis section, the bottom the stripping section, with a 65% single pass CO_2 conversion rate. Steam consumption is 10% lower than for a conventional process.

"The A6000 concept is designed to achieve maximum economies of scale at up to 6,000 t/d.

Revamping

For ammonia revamping options, Casale has proprietary technologies for moderate (up to 130%) and major (up to 200%) capacity increases. The former is based on traditional technologies (for example, pre-reformer, primary reformer expansion, etc.), the latter on a proprietary scheme known as Super Revamping™, comprising the use of an oxygen-blown ATR to reduce plant modifications. Typical plant bottlenecks which can be overcome include increasing compressor capacity via an air compressor booster; a secondary burner modification and alternative, more efficient waste heat boiler, nd replacement of conventional catalyst beds with axial-radial beds.

Revamping urea options include high efficiency reactor trays, and the split flow loop and full condenser configurations, which can increase high pressure loop capacity by 30-50%. For larger capacity increases, Casale has developed the medium splitting concept to overcome the hydraulic limit of the stripper. A new plant section is installed in parallel with the existing HP stripper, and flow from the urea reactor which exceeds the allowable load of the stripper is diverted to a parallel section working at about 18 bar. The MP section is equipped with a decomposer and a condenser and the unreacted carbamate is partially decomposed and the vapours condensed with the aid of carbonate solution from the downstream LP section.

For methanol plants, moderate capacity increases (up to 30%) can be achieved through addition of a pre-reformer; a primary reformer upgrade or partial oxidation reactor and the downstream Casale Isothermal Methanol Converter. When clients demand a huge capacity increase, other options are available, such as CO_2 injection – for example from a neighbouring ammonia or ethylene plant – in combination with the Isothermal Methanol Converter in the synthesis loop; moving to an autothermal reactor and the installation of an additional 'once through reactor'.

Case studies

A number of case studies were also presented. Casale recently upgraded a Toyo-built ammonia plant in Russia at Nevinnomyssk. The plant had originally been designed for a capacity of 1,360 t/d, uprated later to a notional 1,700 t/d, although limitations in air compression and cooling capacity meant that in practise it ran at 1,600-1,650 t/d. As well as expanding the primary reformer with new catalyst tubes and burners and improving compressor and cooling capacities, Casale also revamped the CO_2 removal section and optimised the reformer steam:carbon ratio, and were able to reduce energy consumption while boosting capacity to 2,000 t/d.

There was also a discussion on the design and construction of the world's largest single train methanol plant, the 7,000 t/d Kaveh unit in Iran. The design is based on a conventional steam-reforming unit together with an oxygen-based auto thermal reformer (ATR) for the front-end section, combined with a high-efficiency synthesis section including a Casale IMC reactor (Isothermal Methanol Converter). Final purification of the product is performed in a three-column distillation section; this configuration was chosen for its low specific energy consumption and limited column dimensions. The oxygen necessary for the ATR is provided by an air separation unit outside the plant battery limits, and the methanol plant also exports high-pressure steam to drive the OSBL facilities (mainly the ASU and a power generator). While the construction of the plant has been delayed by international sanctions against Iran, the lifting of many of those issues now means that the plant is scheduled for completion in 2017.

Zuari Agro in Goa, India, has selected Casale to upgrade its urea plant from 1,400 t/d to 1,800 t/d, as well as reducing energy inputs from 6.4Gcal/t urea to 4.9Gcal/t urea, necessitating an overhaul of the associated ammonia plant as well. On the urea side, the synthesis section will be transformed from its original

Toyo total recycle process to an ammonia stripping process, with a new reactor, a new HP carbamate condenser, HP stripper, HP separator and HP ejector. Downstream, this will also be an application for Casale's *Vortex* granulation system, here being used as a prill fattening process.

Meanwhile, on the nitric acid front, Casale presented a study of the 1,500 t/d dual pressure nitric acid plant which GPN and Chemoprojekt designed and built at Grand Quevilly in France in 2009, the world's largest single burner nitric acid plant. The 6m burner was the largest yet designed, and necessitated extensive computational fluid dynamics (CFD) studies to ensure even mixing.

Nitrogen+Syngas index 2016

A complete listing of all articles and news items that appeared in *Nitrogen+Syngas* magazine during 2016.

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 53 54 55 56 57 58 59 60 61 62 63 64

Nitrogen industry news

Country	Nitrogen Industry News	Issue	Pg
Australia	Investigation into ammonia leak	Mar/Apr	10
	Orica expansion approved	Mar/Apr	10
	Oswals settle with Apache	Sep/Oct	11
	Pilbara AN plan begins commissioning	May/Jun	12
Azerbaijan	SOCAR start-up scheduled for 2018	May/Jun	13
Bangladesh	Kafco faces seasonal shutdown again	May/Jun	12
Brazil	Vale selling fertilizer business to Mosaic	Nov/Dec	11
	Yara considers purchase of Vale fertilizers	Jul/Aug	12
Brunei	India considering Brunei joint venture	Mar/Apr	11
Canada	Agrium in merger talks with PotashCorp	Sep/Oct	10
	AN code of practise now in force	Jan/Feb	12
	Iffco confirms urea plant now on hold again	Jan/Feb	12
	Worker dies after ammonia leak at Medicine Hat	Jan/Feb	12
China	AN blamed for Tianjin explosion	Mar/Apr	10
	Start-up for largest single train melamine plant	Nov/Dec	11
	Topsoe establishes new R&D centre	Mar/Apr	10
Egypt	KBR re-starts work at Kima	Mar/Apr	12
Equatorial Guinea	EPC contract awarded for urea complex	Mar/Apr	11
France	Borealis buys AN storage site	Jul/Aug	13
	IFA inaugurates Global Fertilizer Day	Nov/Dec	12
Germany	Clariant partnership inaugurates new research centre	Jul/Aug	10
	Explosion kills three at Ludwigshaven	Nov/Dec	12
	Initiative to buy CERs from nitric acid projects	Jan/Feb	12
	Pumps for extreme operations	Mar/Apr	12
	Shell and UFT collaborate on S-enhanced urea	May/Jun	10
India	Ammonia supply disruption at Haldia	May/Jun	12
	Coal-based urea plant proposal	May/Jun	12
	Incremental progress on reviving old plants	Sep/Oct	12
	Investigation into AN dumping	Sep/Oct	12
	New catalyst recycling facility	Sep/Oct	13
	New nitric acid plant for Deepak	Sep/Oct	12
	Progress stalled on plant re-start	Jan/Feb	13
	SPIC begins switch from naphtha	Jan/Feb	13
	Toyo wins Chambal contract	May/Jun	12
	Urea prices to be frozen	Jul/Aug	12
	Yara acquires Tata's urea business	Sep/Oct	12
Indonesia	Financial closure for ammonia project	Jul/Aug	13
	Indonesia foils AN smuggling attempts	Nov/Dec	11
Iran	Gas agreement signals progress on JV	May/Jun	10
	Joint venture formed for urea development	Nov/Dec	10
	Partner selected for Indian urea development	Jul/Aug	12
	Shiraz ammonia-urea plant commissioned	Jan/Feb	13
	Start-up for Marvdasht plant	Sep/Oct	13
Israel	New ammonia plant ready for tender	Jul/Aug	13
	Threat to ammonia tank	Mar/Apr	12
Italy	Tecnimont earnings up for 2015	May/Jun	13
Malaysia	Ammonia to form part of phosphate complex	Mar/Apr	11
	Chinese investors considering new urea plant	Sep/Oct	12
	Samur to come on-stream in 2H 2016	May/Jun	13
Netherlands	Stamicarbon launches HSE portal	Sep/Oct	10
	Stone laying ceremony for new granulation plant	May/Jun	10
Nigeria	Abraaj Group buys into Indorama	Nov/Dec	12
	Indorama urea complex enters commissioning	May/Jun	10
Pakistan	Budget includes major package for agriculture	Jul/Aug	12
Poland	State to buy out Acron share in Azoty	Nov/Dec	12

Country	Nitrogen Industry News	Issue	Pg
Russia	Control systems upgrade at Togliatti	Jan/Feb	12
	Finance secured for ammonia plant	Jan/Feb	12
	Turbine upgrade at Togliatti	Sep/Oct	11
	Uralchem completes ammonia revamp	Jan/Feb	10
Saudi Arabia	Ma'aden begins trial operations at ammonia plant	Nov/Dec	10
Switzerland	ChemChina to buy Syngenta	Mar/Apr	10
Taiwan	Increase in high purity ammonia production	Jan/Feb	10
Tanzania	Construction on urea plant to begin this year	Jul/Aug	12
Turkey	Turkey bans sale of ammonium nitrate	Jul/Aug	10
Ukraine	No takers for OPZ	Sep/Oct	10
	OPZ to be privatised	Jul/Aug	12
UK	Treatment for wastewater streams	Mar/Apr	12
USA	Arkansas ammonia plant up and running	Jul/Aug	10
	CF Industries start up new UAN plant	May/Jun	11
	CF suspends work on Courtright expansion	Nov/Dec	10
	Cronus nitrogen plant delayed	Jul/Aug	10
	CSB report on West calls for tighter standards	Mar/Apr	10
	CVR completes purchase of Rentech	May/Jun	12
	Dyno Nobel completes new ammonia plant	Nov/Dec	10
	Foster Wheeler to manage ammonia plant	Mar/Apr	11
	Ground broken on small scale ammonia plant	May/Jun	11
	IGCC plant bought for ammonia production	Jul/Aug	10
	ITC to rule on alleged dumping of AS	Sep/Oct	10
	KBR buys Ecoplanning, Plinke and Weatherly	Jan/Feb	10
	KBR Weatherly launches new nitric acid technology	Sep/Oct	11
	LSB finances new nitrogen facilities	Jan/Feb	10
	New ammonia plant for Nebraska?	Jan/Feb	10
	Port Neal nears completion	Sep/Oct	11
	Start-up for new CF urea plant	Jan/Feb	10
	TFI wins legal challenge against ammonia rule	Nov/Dec	10
	TKIS to build new fertilizer plant	Mar/Apr	11
Uzbekistan	Casale to modernise nitric acid plant	Mar/Apr	11
Vietnam	Coal-based producers in trouble	Nov/Dec	11

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 53 54 55 56 57 58 59 60 61 62 63 64

Syngas news

Country	Syngas News	Issue	Pg
Australia	Environmental approvals for Tassie Shoals extended	Sep/Oct	16
	Feasibility study on GTL plant	Sep/Oct	16
	Linc Energy goes into administration	May/Jun	15
Azerbaijan	SOCAR to acquire AzMeCo	Nov/Dec	15
Canada	Methanol a possible option for British Columbia	Sep/Oct	16
	Methanol ships go into service	May/Jun	15
Chile	Methanex secures gas supply	Sep/Oct	16
China	Air Liquide strengthens Chinese partnership	May/Jun	15
	Another new MTO facility	Sep/Oct	15
	Global agreement on methanol-fuelled trucks	May/Jun	14
	Honeywell breaks ground on MTO catalyst plant	Jul/Aug	15
	New ASU for methanol production	Mar/Apr	15
	SES signs agreement for 20 gasification plants	May/Jun	14
Denmark	Topsoe publishes research in improved catalysts	Jul/Aug	14
Europe	EMSA positive on methanol as shipping fuel	Jul/Aug	15
Germany	CO_2 to chemicals project	Jul/Aug	15
	Linde confirms merger talks with Praxair	Sep/Oct	16
Iran	Topsoe to license methanol technology	Mar/Apr	15
Japan	Hydrogen from renewables	Nov/Dec	15
Netherlands	Waste to methanol plant proposed	Nov/Dec	14
Pakistan	Progress on UCG project	Mar/Apr	15
Peru	New hydrogen plant	Nov/Dec	15
Russia	Ammonia-methanol complex planned for East coast	Nov/Dec	14
	MHI to build ammonia-methanol plant	May/Jun	15
Southeast Asia	Reforming methanol to hydrogen	Sep/Oct	15
South Korea	Completion for methanol-fuelled ship	Sep/Oct	17
	Start-up for gasification power plant	Sep/Oct	17
T'dad & Tobago	Methanol and DME plant renegotiated	Sep/Oct	14
UAE	Agreements signed for GTL commercialisation	Jan/Feb	15
UK	Global methanol capacity to reach 184 million t/a	Jul/Aug	14
	First shale gas arrives in UK	Nov/Dec	14
USA	Another delay for Mississippi Power	Sep/Oct	14
	Carbon dioxide to methanol process	Mar/Apr	14
	Celanese considering second methanol plant	Jul/Aug	14
	China still driving methanol market says HIS	Sep/Oct	14
	Construction complete at ENVIA GTL plant	Nov/Dec	14
	Construction contract awarded for Natgasoline plant	Nov/Dec	14
	CTL plant mooted for Utah	Jan/Feb	14
	G2X buys into Beaumont methanol project	May/Jun	14
	Ground broken on new methanol plant	Mar/Apr	14
	Landfill GTL plant agreement	Mar/Apr	14
	Linc files for Chapter 11 in US	Jul/Aug	14
	NWIW "pauses" methanol plant application	Mar/Apr	14
	NWIW seeks to improve environmental credentials	Jan/Feb	14
	Plan to relocate methanol plants to Virginia	Sep/Oct	14
	Primus to build modular methanol plant	May/Jun	14
	Progress on Kalama methanol plant	Nov/Dec	15
	Refineries turn to over the fence hydrogen	Mar/Apr	15
	Start-up for second Methanex methanol plant	Jan/Feb	14
	Start-up for pilot GTL plant	Sep/Oct	14
	Technip awarded contract for hydrogen plant	Jan/Feb	14
	Tecnimont to develop gas-based ethylene technology	Jul/Aug	14
	Topsoe to license new methanol plant	Mar/Apr	14
	Yet more delays for coal gasification plant	May/Jun	14
	Yuhuang pressing ahead with methanol project	Jul/Aug	14
Uzbekistan	GTL plant "still under development"	Jan/Feb	15
Vietnam	PetroVietnam considering methanol JV	Jan/Feb	14

Nitrogen project listing 2017

Contractor	Licensor	Company	Location	Product	mt/d	Status	Start-up date
ALGERIA							
n.a.	Casale	Fertial	Arzew	Ammonia	1,000	RE	2017
AZERBAIJAN							
Samsung	Haldor Topsoe	SOCAR	Sumgait	Ammonia	1,200	UC	2018
Samsung	Stamicarbon	SOCAR	Sumgait	Urea	2,000	UC	2018
BANGLADESH							
Uhde India Pvt	UFT	Kafco	Chittagong	Urea	2,100	RE	2017
BELARUS							
thyssenkrupp I.S.	thyssenkrupp I.S.	Grodno Azot	Grodno	Nitric acid	1,200	UC	2018
thyssenkrupp I.S.	thyssenkrupp I.S.	Grodno Azot	Grodno	Ammonium nitrate	3,500	UC	2018
BOLIVIA							
Samsung	KBR	YPFB	Bulo Bulo	Ammonia	1,200	C	2016
Samsung	TEC	YPFB	Bulo Bulo	Urea	2,100	C	2016
BRAZIL							
Technip, TEC	Haldor Topsoe	Petrobras	Uberaba	Ammonia	1,500	BE	2017
Tecnimont	KBR	Petrobras	Tres Lagoas	Ammonia	2,200	UC	2018
Tecnimont	Stamicarbon, UFT	Petrobras	Tres Lagoas	Urea	3,600	UC	2018
CANADA							
Casale	Casale	Koch Nitrogen	Brandon, MN	Urea	700	RE	2016
Casale	Casale	CF Industries	Courtright, ON	Urea	1,100	RE	On hold
n.a.	Saipem	Agrium	Redwater, AL	Urea	2,600	RE	2017
CHINA							
Casale	Casale	Inner Mongolia Manshi	Erdos	Ammonia	1,630	RE	2016
Casale	Casale	Henan Junhua	Zhumadian, Henan	Ammonia	2,000	RE	2016
Casale	Casale	Henan Jinkai	Kaifeng, Henan	Ammonia	2,000	RE	2017
Casale	Casale	Shenua Ningxia	Ningxia	Ammonia	500	RE	2016
CCEC	KBR	Inner Linggu Chem Co	Yixing, Jingsu	Ammonia	1,500	C	2016
CCEC	Stamicarbon	Inner Linggu Chem Co	Yixing, Jingsu	Urea	2,700	C	2016
n.a.	Stamicarbon	Inner Mongolia Huajin	Panjin	Urea	2,860	C	2017
Huafu	Saipem	Wulan Coal Group	Wulanhaote	Urea	4,000	UC	2017
Henan Xinlianxin	Stamicarbon	Henan Xinlianxin Fert	Xinxiang	Urea	+40	RE	2018
EGYPT							
Tecnimont	KBR	Kima	Aswan	Ammonia	1,200	UC	2018
Tecnimont	Stamicarbon	Kima	Aswan	Urea	1,575	UC	2018
thyssenkrupp I.S.	thyssenkrupp I.S.	MOPCO	Damietta	Ammonia	2 x 1,200	C	2016
thyssenkrupp I.S.	Stamicarbon	MOPCO	Damietta	Urea	2 x 1,925	C	2016
thyssenkrupp I.S.	thyssenkrupp I.S.	EHC	Suez	Nitric acid	850	C	2016
thyssenkrupp I.S.	thyssenkrupp I.S.	EHC	Suez	Ammonium nitrate	1,050	C	2016
FRANCE							
Casale	Casale, UFT	Borealis Chimie	Grandpuits	Urea	850	RE	2016
GABON							
Technip	Haldor Topsoe	Gabon Fertilizer Co	Port Gentil	Ammonia	2,200	DE	On hold
Technip	Saipem/UFT	Gabon Fertilizer Co	Port Gentil	Urea	3,850	DE	On hold

1 47 2 48 3 49 4 50 5 51 6 52 7 53 8 54 9 55 10 56 11 57 12 58 13 59 14 60 15 61 16 62 17 63 18 64 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

Contractor	Licensor	Company	Location	Product	mt/d	Status	Start-up date
HUNGARY							
thyssenkrupp I.S.	thyssenkrupp I.S.	Nitrogenmucek	Petfurdo	Nitric acid	1,150	UC	2017
thyssenkrupp I.S.	thyssenkrupp I.S.	Nitrogenmuvek	Petfurdo	Ammonium nitrate	1,550	UC	2017
INDIA							
Casale	Casale	Zuari	Goa	Urea	1,050	RE	2017
Casale	Casale	Iffco	Kalol	Ammonia	1,140	RE	2016
Casale	Stamicarbon	Iffco	Kalol	Urea	1,780	RE	2016
Casale	Casale	Iffco	Phulpur	Ammonia	1,850	RE	2016
Casale	Saipem	Iffco	Phulpur	Urea	2,115	RE	2016
Casale	Casale	Iffco	Phulpur	Ammonia	1,215	RE	2016
Casale	Saipem	Iffco	Phulpur	Urea	1,600	RE	2016
Casale	Casale	Iffco	Aonla	Ammonia	2 x 1,850	RE	2016
Casale	Saipem	Iffco	Aonla	Urea	2 x 1,600	RE	2016
PDIL	KBR	Matix Fert & Chem	Panagarh	Ammonia	2,200	UC	2016
Saipem	Saipem	Matix Fert & Chem	Panagarh	Urea	3,850	UC	2016
n.a.	n.a.	Deepak F&C	Dahej, Gujarat	Nitric acid	725	DE	2018
Engineers India Ltd	Haldor Topsoe	RCFL	Ramagundam	Ammonia	2,200	BE	2019
Engineers India Ltd	Saipem	RCFL	Ramagundam	Urea	3,850	BE	2019
TEC	KBR	Chambal Fert & Chem	Gadepan	Ammonia	2,200	CA	2019
TEC	TEC	Chambal Fert & Chem	Gadepan	Urea	2 x 2,000	CA	2019
n.a.	n.a.	FCIL	Talcher, Odisha	Ammonia	2,700	P	2020?
n.a.	n.a.	FCIL	Talcher, Odisha	Urea	3,850	P	2020?
n.a.	n.a.	FCIL	Talcher, Odisha	Ammonium nitrate	1,000	P	2020?
INDONESIA							
TEC	KBR	PAU	Sulawesi	Ammonia	1,900	UC	2018
TEC/PT Rekayasa	KBR	Pusri	Palembang	Ammonia	2,750	C	2016
TEC/PT Rekayasa	TEC	Pusri	Palembang	Urea	2,000	C	2016
IRAN							
STAC	Stamicarbon	Pardis Petrochemical	Pars	Urea	3,250	C	2016
Hampa	Stamicarbon	Lordegan Petrochemical	Lordegan	Urea	3,250	BE	2018
Hampa	Stamicarbon	Zanjan Petrochemical	Zanjan	Urea	3,250	BE	2018
n.a.	Saipem, UFT	Hengan Petrochemical	Assaluyeh	Urea	3,250	UC	2018
Hampa	Stamicarbon	Golestan Petrochemical	Golestan	Urea	3,250	BE	On hold
n.a.	n.a.	Indo-Iranian JV	Chabahar	Ammonia	2,200	P	n.a.
n.a.	n.a.	Indo-Iranian JV	Chabahar	Urea	3,800	P	n.a.
IRAQ							
NFC	KBR	NFC	Baiji	Ammonia	1,200	RE	On hold
NFC	Stamicarbon	NFC	Baiji	Urea	2,250	RE	On hold
ISRAEL							
n.a.	n.a.	State owned	Mishor Rotem	Ammonia	360	P	2020
MALAYSIA							
MHI	Haldor Topsoe	Petronas	Siptang	Ammonia	2,100	C	2017
MHI	Saipem/UFT	Petronas	Siptang	Urea	3,500	C	2017
MEXICO							
n.a.	Saipem	Pemex	Pajaritos	Urea	1,500	RE	n.a.

KEY

BE: Basic engineering
C: Completed/commissioning
CA: Contract awarded
DE: Design engineering
FS: Feasibility study
n.a.: Information not available
P: Planned/proposed
RE: Revamp
UC: Under construction
Conversion:
1 t/d of hydrogen = 464 Nm³/h
1 t/d of natural gas = 1,400 Nm³/d

Contractor	Licensor	Company	Location	Product	mt/d	Status	Start-up date
NETHERLANDS							
Tecnimont/Yara	UFT	Yara	Sluiskil	Urea	1,625	RE	2018
NEW ZEALAND							
n.a.	Casale	Ballance Agri-Nutrients	Kapuni	Urea	1,400	RE	2019
NIGERIA							
TEC/Daewoo	KBR	Indorama	Port Harcourt	Ammonia	2,400	C	2016
TEC/Daewoo	TEC	Indorama	Port Harcourt	Urea	4,000	C	2016
Saipem	Haldor Topsoe	Dangote Fertilizer Ltd	Agenbode	Ammonia	2 x 2,200	UC	2017
Saipem	Saipem/UFT	Dangote Fertilizer Ltd	Agenbode	Urea	2 x 3,850	UC	2017
ROMANIA							
Chemoprojekt	Casale	Azomures	Targu Mures	Ammonia	2 x 1,050	RE	2016
Chemoprojekt	Stamicarbon	Azomures	Targu Mures	Urea	1,425	C	2017
RUSSIA							
NIIK	NIIK, Stamicarbon	Minudobrenija Perm	Perm	Urea	1,720	RE	2016
Casale	Casale	EuroChem	Nevinnomyssk	Urea	1,600	RE	2016
Casale	Casale	Togliatti Azot	Togliatti	Urea	2,200	DE	2019
Tecnimont	KBR	EuroChem	Kingisepp	Ammonia	2,700	BE	2018
Tecnimont	KBR	EuroChem	Nevinnomyssk	Ammonia	2,700	BE	n.a.
n.a.	Stamicarbon	Uralchem	Perm	Urea	+770	RE	2019
Saipem	Sapiem, UFT	Baltic Urea Plant	St Petersburg	Urea	3,500	DE	On hold
MHI/Sojitz	Haldor Topsoe	PhosAgro	Cherepovets	Ammonia	2,200	BE	2017
Chemoprojekt	Stamicarbon	PhosAgro	Cherepovets	Urea	1,500	UC	2018
NIIK, Chemoprojekt	Stamicarbon	PhosAgro	Cherepovets	Urea	1,500	RE	2017
SAUDI ARABIA							
Daelim	thyssenkrupp I.S.	Ma'aden	Ras al Khair	Ammonia	3,300	C	2016
eTec	thyssenkrupp I.S.	Safco IV	Al Jubail	Ammonia	3,670	RE	2017
SLOVAKIA							
Chemoprojekt	Haldor Topsoe	Duslo Sala	Sala	Ammonia	1,600	RE	2018
SWEDEN							
Chemoprojekt	Casale	Yara	Koping	Nitric acid	685	UC	2017
n.a.	n.a.	Yara	Koping	Ammonium nitrate	1,360	RE	2017
TANZANIA							
Ferrostaal	Haldor Topsoe	Tanzanian Petroleum	Mtwara	Ammonia	2,200	DE	2020
Ferrostaal	n.a.	Tanzanian Petroleum	Mtwara	Urea	3,800	DE	2020
TURKEY							
n.a.	Haldor Topsoe	Eti Bakir	Mardin	Ammonia	300	UC	2017
thyssenkrupp I.S.	thyssenkrupp I.S.	Bagfas	Bandirma	Nitric acid	1,195	C	2016
thyssenkrupp I.S.	thyssenkrupp I.S.	Bagfas	Bandirma	Ammonium nitrate	1,550	C	2016
TURKMENISTAN							
MHI	Haldor Topsoe	Turkmenkhimiya	Garabogaz	Ammonia	2,000	CA	2018
MHI	Saipem/UFT	Turkmenkhimiya	Garabogaz	Urea	3,500	UC	2017
UNITED STATES							
thyssenkrupp I.S.	thyssenkrupp I.S.	CF Industries	Port Neal, IA	Ammonia	2,200	C	2017
thyssenkrupp I.S.	Stamicarbon/UFT	CF Industries	Port Neal, IA	Urea	3,490	C	2017
OCI Construction	KBR	Iowa Fert Co	Wever, IA	Ammonia	2,000	C	2017
OCI Construction	Stamicarbon/UFT	Iowa Fert Co	Wever, IA	Urea	2,200	C	2017
OCI Construction	thyssenkrupp I.S.	Iowa Fert Co	Wever, IA	Nitric acid	1,530	C	2017
OCI Construction	thyssenkrupp I.S.	Iowa Fert Co	Wever, IA	Ammonium nitrate	1,900	C	2017
OCI Construction	thyssenkrupp I.S.	Iowa Fert Co	Wever, IA	UAN	4,300	C	2017
KBR	Stamicarbon, UFT	Agrium	Borger, TX	Urea	1,800	RE	2017

Contractor	Licensor	Company	Location	Product	mt/d	Status	Start-up date
UNITED STATES continued							
KBR, Casale	KBR, Casale	Agrium	Borger, TX	Ammonia	1,900	RE	2017
IHI	Stamicarbon	Dakota Gasification	Beulah, ND	Urea	1,000	UC	2017
KBR	KBR	Dyno Nobel	Waggaman, LA	Ammonia	2,400	C	2016
Black & Veatch	KBR, Casale	Koch Nitrogen	Enid, OK	Ammonia	1,680	RE	2016
Black & Veatch, KBR	Stamicarbon	Koch Nitrogen	Enid, OK	Urea	2,200	C	2017
Linde	Linde	Simplot Phosphates	Rock Springs, WY	Ammonia	600	UC	2017
Casale	Casale	Rentech Nitrogen	East Dubuque, IL	Ammonia	1,180	RE	2016
SNC Lavalin	Casale	Summit Clean Energy	Pennwell, TX	Ammonia	n.a.	DE	On hold
SNC Lavalin	Saipem	Summit Clean Energy	Pennwell, TX	Urea	2,245	DE	On hold
n.a.	Haldor Topsoe	BioNitrogen	Florida	Ammonia	300	DE	2017
Tecnimont	KBR	Cronus Chemical	Tuscola, IL	Ammonia	2,200	CA	2020?
Tecnimont	Stamicarbon	Cronus Chemical	Tuscola, IL	Urea	3,850	CA	2020?
KBR	KBR	BASF/Yara	Freeport, TX	Ammonia	2,270	UC	2017
n.a.	Stamicarbon	PCS Nitrogen	Geismar, LA	Urea	+450	RE	2018
Matrix Service	n.a.	Fortigen LLC	Geneva, NE	Ammonia	90	UC	2017
n.a.	n.a.	Phibro	Wabash River, IN	Ammonia	1,500	RE	2018
UZBEKISTAN							
MHI	Haldor Topsoe	NavoijAzot	Navoij	Ammonia	2,000	UC	2018
MHI	Saipem, UFT	NavoijAzot	Navoij	Urea	1,750	UC	2018
n.a.	Casale	NavoijAzot	Navoij	Nitric acid	1,500	UC	2018
VIETNAM							
Technip	thyssenkrupp I.S.	PetroVietnam	Phu My	Ammonia	1,600	RE	2017

Early detection of process risks

The implementation of a new software, Dynamic Risk Analyzer™ (DRA), developed by Near-Miss Management and based on a groundbreaking early risk detection technology, is outlined in this article. DRA assesses the risk level of plant operations and identifies early indicators of developing process problems. By utilising such an early risk detection system, the operating teams can assess and resolve process issues at their initiation stages – driving a proactive risk management culture and workflow. Real-life examples, where process issues were detected and addressed early on using DRA technology, are presented.

Minimising risks related to process safety and reliability is the highest priority for operating teams today. Although plant operations are equipped with process monitoring tools, current applications have limitations, particularly, lacking information on developing risks, which are typically hidden in the data and are not visible easily.

Most of the incidents and unexpected process failures can be avoided if the operating team gets timely information about developing risks and takes preventative action. Post-incident investigations show that there are several near misses that occur before these events evolve (gradually or often, rapidly) to become abnormal situations[1-4]. While advances have been made in process risk management in the past few years, there still remain significant information gaps that prevent facilities from proactively identifying process risks. The latest process monitoring techniques provide clear insights on current operating conditions, however, they are not predictive in nature.

With new advances in information technology, a typical industrial plant operation monitors hundreds (even thousands) of parameters continuously, generating on the order of 10 million to 50 million data points every day. Over the past few years, although facilities have become 'data rich', they are 'information poor' – this is typically referred to as the 'big data challenge'. There is a great need for tools that can analyse this 'big data' and inform plant personnel of changes in the risk profile of the plant over time with indication of potentially evolving disturbances to help avert unplanned shutdowns and accidents.

Big data is indeed big – typically, over 1 billion data points are recorded every month with just 500 tags (recording sensor measurements every second). It is often characterised by the four Vs: volume, variety, velocity, and variability, which change with time. Lost in the flood of this big data are indicators that can help plants understand the dynamically changing risks and avoid some of the losses the chemical and petrochemical industry experience every year (due to unexpected failures). Research confirms that taking a different-in-kind approach to harnessing big data – based on processing the information directly, from a risk perspective, with advanced data mining techniques – creates a wealth of insights that were previously unavailable[5]. This has significant potential to transform the way facilities operate, and to reduce unexpected disruptions.

Equipped with insights from this full range of data pinpointing changing risk levels on a dynamic basis, a plant operations team can identify when problems actually start. Going further, plant management and engineers can utilise leading indicators ex-ante to take proactive measures to prevent and avoid operational problems. Ultimately, this type of knowledge can help engineers and safety personnel to monitor the effectiveness of existing risk reduction measures and to point out issues early on, so that management can allocate resources to the most needed areas before they become actual problems.

This article provides an overview of the current process risk analysis methods and the gaps in the risk assessment landscape. It introduces a new approach for proactive risk assessment to help facilities operate safely and reliably. To demonstrate this vision, the use and implementation of Dynamic Risk Analyzer (DRA) software at Asean Bintulu Fertilizer (ABF) is discussed, along with four real-life case studies.

Current risk analyses and their limitations

Improved process risk management is the primary outcome of the widely used Process Safety Management (PSM) standard, which is promulgated by the US Occupational Safety and Health Administration to maintain and improve safety, operability, and productivity of plant operations. While advances have been made in the process risk assessment area in the last decade, there still remain significant gaps causing facilities to continually look for new solutions. The current risk analysis techniques and associated limitations are as follows[5]:

Quantitative risk assessment (QRA)

Typically, QRAs are conducted once every 3-5 years by most facilities. These use various data sources available to the industry, such as incident data, material safety data, and equipment and human reliability data, to identify incident scenarios and evaluate their risks by defining the probability of failure and their potential consequences. They help users identify areas for risk reduction.

Limitations: Because QRA mostly involves incident and failure data – excluding day-to-day process and alarm data that contain information on precursor events – it has limited predictive power. Interestingly, a summary report[6] by the Joint Research Centre and Denmark Risk National Laboratory of the European Commission indicates that risk estimates based on generic reliability/failure databases are prone to biases and could result in large deviations depending on data sources. Their project employed seven partners that conducted risk analyses for the same ammonia storage facility, finding "large differences in frequency assessments of the same hazardous scenarios." For these reasons, the importance of utilising process-specific databases for objective risk analyses has been gaining recognition.

Safety audits

Many facilities conduct safety, health and environmental audits using both internal teams and consulting companies. The frequency and effectiveness of safety audits depend highly on the resource availability for the facility. In most cases, safety professionals with support from engineers, operators and sometimes even managers periodically review operating procedures and safety records, and conduct interviews about safety practices.

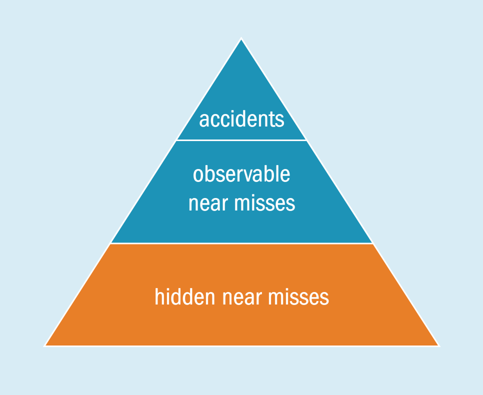
Limitations: Formal, in-depth, safety audits are conducted periodically, the frequency ranging from once a year (in rare cases more than once a year) to once in several years. An integral part of these audits is to review incident history and observable near misses that are reported by employees. The latter of which depends upon the safety culture at the facility and may not always provide an accurate picture of risks.

Furthermore, these approaches do not have the capability to monitor the change in the process risk levels in real, or even near, time.

Operations management and manufacturing intelligence tools

Operations management and manufacturing intelligence software provide KPIs (key performance indicators) for performance monitoring of operations, and assessment of availability/effectiveness of equipment. They focus on trending, reporting, and visual analytics of a select data slice, which help users monitor the variability of different parameters in a time period (shift, day, week, etc.).

Fig 1: **Extended safety pyramid**



Limitations: These systems fall short when users need insights on parts of operation that are becoming riskier. These situations require detailed analysis of operating conditions to identify new changes, which is not the focus of these systems. With aging equipment and expected departure of many seasoned operators from the workforce, this handicap becomes even more considerable.

Condition based monitoring tools

These tools are mainly designed for equipment condition monitoring. They identify abnormal situations in real- or near-time by comparing equipment's performance with its expected behaviour and alerting the user when there is a mismatch. Both model-driven (based on quantitative process models) as well as data-driven tools (based on clustering and dimensionality reduction approaches) are available in the market that help operators take immediate corrective actions as real-time alerts are dispatched.

Limitations: Many of them require continuous efforts in maintaining the baseline. In addition, they often involve remote monitoring and diagnosis of the data at an offsite facility, which is a resource and capital intensive project.

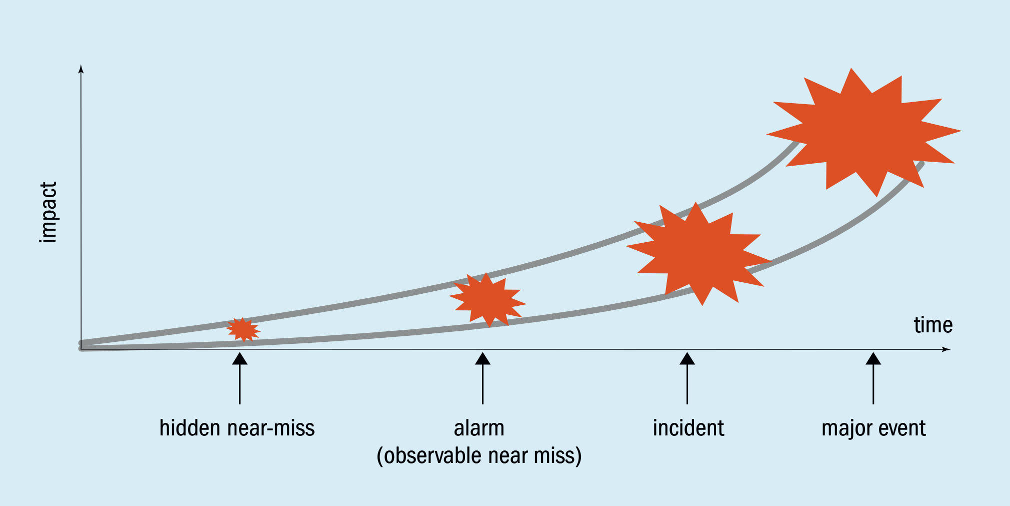
Thus, the need is clear for an approach that helps facilities become proactive in risk detection and close the existing gaps. Next, a new approach is outlined that identifies risk levels and drivers dynamically and can help busy plant personnel harness the insights in the big data and take appropriate actions rapidly.

Taking a different approach

Accidents are rare events, which occur when a series of failures of risk management barriers occur in succession – implying a 'chance' factor involved in their occurrences. Post-accident investigations show that there are typically several near-misses or precursors that occur over time before their occurrence[1-4]. This concept is captured in the well-known "safety pyramid". Fig. 1 introduces an extended version of the safety pyramid, indicating two categories of near-misses that are precursors to accidents. First is observable near misses, which refer to events that are typically notable by the operations team, such as, equipment failures, leaks, etc. Second is hidden near misses, which refer to events that can only be detected through rigorous data analysis and are typically not observable to human eye. The novel approach of identifying hidden near misses in the process and alarm databases permits detection of operational problems at their developing stages. This approach forms the backbone of Dynamic Risk Analyzer (DRA) software, which analyses process data to determine risk indicators.

As previously mentioned, with new advances in information technology, a typical industrial plant operation monitors

Fig 2: **Hidden near miss and evolution of a major event**



hundreds (sometimes thousands) of parameters continuously, generating extensive data sets, exceeding the billion mark within a few weeks of operation. The approach of identifying hidden near misses requires advanced data-mining techniques to sift through this big data to find new abnormalities that often cannot be detected using manual/visual data analysis or engineering models. This information can then be used to estimate risk that indicate likelihood of normal conditions escalating to abnormal levels, providing insights on potential performance issues in the operations.

Fig. 2 shows the typical evolution of a major event. By identifying the hidden near misses, before the alarms are triggered, the techniques behind DRA software enables the operations team to address the events at their formation stage, before they become visible or threatening. The dynamic risk levels guide plant personnel to the sources of the risk – to deploy the right resources in a timely manner, to plan just-in-time maintenance, and to head off potential problems – several days or even weeks in advance. The results can be made accessible to all users (plant managers, supervisors, engineers, reliability and maintenance crew, as well as operators) to promote transparency among the operating team and to complement their existing predictive maintenance, PSM, hazard identification, and quantitative risk analysis activities.

Use of DRA at ABF operations

Asean Bintulu Fertilizer (ABF), a subsidiary of PETRONAS, produces 700,000 tonnes of urea annually. Due to the nature of materials involved and interdependency between its operating units, minimising risks related to process safety and reliability is the highest priority for ABF's operating team. Unsafe plant conditions may lead to process safety incidents, which in the worst case, can cost lives, risk the business, and jeopardise the reputation of the organisation. Similarly, downtime, due to unreliability of equipment, can lead to opportunity loss. ABF is equipped with the latest tools in process monitoring, such as Alarm Management System (AMS) and Plant Information Management System (PIMS), and historians, however, these tools are not predictive in nature. In real life situations, most of the time critical alarms are triggered too late for any proactive corrective actions to be taken.

In 2014, ABF decided to change the status quo and adopt a proactive organisational culture and workflow. The vision was to have a leading indicators system that can inform the operations team about plant risks early on, giving them sufficient time to take strategic corrective actions and confidently maintain safe and reliable operation.

The first step towards accomplishing such resilience was selection of new software, Dynamic Risk Analyzer (DRA), as the process risk management platform at their facility. Instilling awareness and responsibilty was given a high priority during the DRA implementation. The user base ranged from top management to the frontliners in the plant i.e shift superintendent, operation technicians, etc. Focus groups were formed to formulate detailed training program for each group, ranging from basic principles to overall vision. A series of training sessions were carried out during normal working days and shift hours to cover all identified key personnel. A simple step by step guideline on the tool was also developed so that the knowledge can be transferred and stored within the organisation. Easy web-based access ensured the risk results to be accessed from anywhere within the organisation's network.

During the installation and training, the focus remained on cultivating a proactive response culture, that is, once a process issue is identified by DRA and confirmed by the team, the next step involved coming-up with a solution to reduce or eliminate the risk.

ABF believed that shifting into proactive approach in dealing with risks and threats could not be achieved just by attending the training and learning about the system alone. It had to be embedded into ABF work flow to ensure continuity, sustenance and improvement. Over the past two years, ABF management has worked hard to achieve this vision. The leading indicators are now reported and discussed during the morning Area Based Team (ABT) meetings as a permanent agenda item. Based on the outcomes from those discussions, a mitigation action plan is devised and status updates are reported in subsequent meetings until the change is normalised or fixed. A mitigation that requires additional resources (particularly, monetary) is escalated to the ABF management.

With this arrangement, ABF now confidently maintains the safety and reliability of its plant facilities, avoiding incidents and downtime, and importantly, remains a highly profitable organisation. Fig. 3 shows the risk schematics in the DRA software. Through analysis of large volumes of past and current process data, the latest plant risk indices are delivered autonomously to the operating team, along with risk status for individual tags. This allows them to drill down and conduct detailed resolution of the risk drivers on a daily basis.

Fig 3: **DRA risk overview**

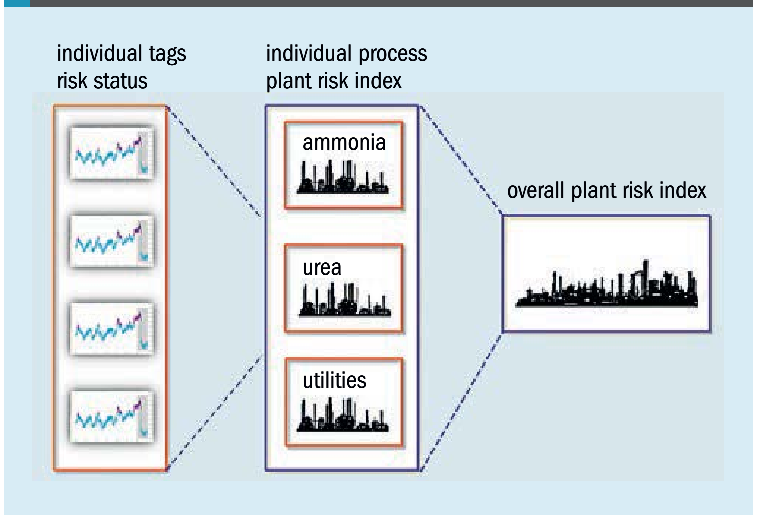
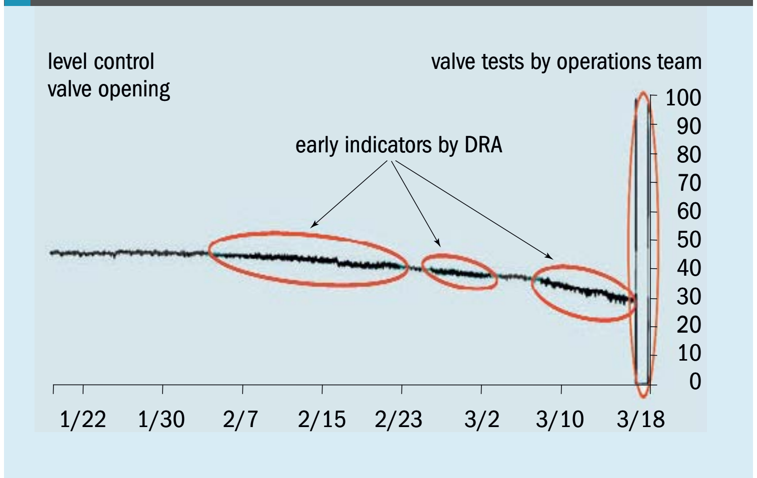


Fig 4: **60 day plot of level control valve opening along with early indicators pointed by DRA**



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 53 54 55 56 57 58 59 60 61 62 63 64

Case studies

Since embarking on utilising DRA in daily risk assessment, ABF has benefited significantly by early identification of plant problems leading to avoidance of potential process safety and plant reliability issues. Four case studies are considered as examples:

Early identification of level control valve failure

Fig. 4 shows a recent plot of a level control valve opening from mid-January to mid-March (60 days). This control valve is located in the tail gas recovery section operating at 115 barg.

As evident, it started experiencing a decreasing trend in early February although there was no change in the associated level indicator. This behaviour was highlighted through the risk indicators generated by DRA and prompted the maintenance team for investigation.

By pointing out this potential problem early on, this risk information provided the maintenance team with ample time to make the necessary preparation to service the valve and hence, avoid any major problem with regards to production and safety.

Fig. 5 shows the valve plug with some erosion (picture taken during servicing).

Fig 5: **Valve plug**

Early identification of faulty controller for ammonia tank base heater temperature

Maintaining base heater temperature above 0°C (32°F) is essential in ensuring the integrity of the ammonia storage tank. Low tank base temperature may result in cracks, which can cause potential release of ammonia into the environment (major loss of primary containment). In April 2015, one of the ammonia storage tank base heater temperature indicator started showing risk indicators – see the 60 day plot in Fig. 6. This triggered the Area Based Team to review the temperature indicator. The investigation led to finding of faulty temperature controller and subsequently, its rectification. Their findings also triggered checks on other temperature indicators and controllers – ensuring their reliability as well.

Ammonia tank base temperature readings, although available in PIMS and DCS, were not normally monitored as critical parameters. Prior to this, changes in the ammonia tank base temperature (before reaching the alarm levels) would not be easily detected as that depended on the keen eyes or vigilance of panel operators.

Fig 6: **60 day plot of ammonia tank base temperature**

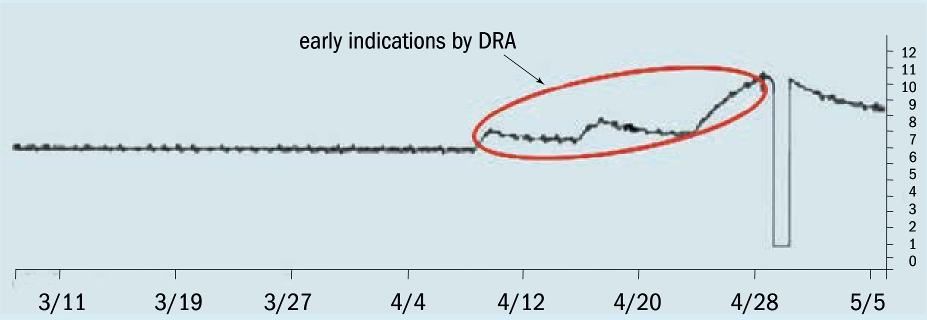
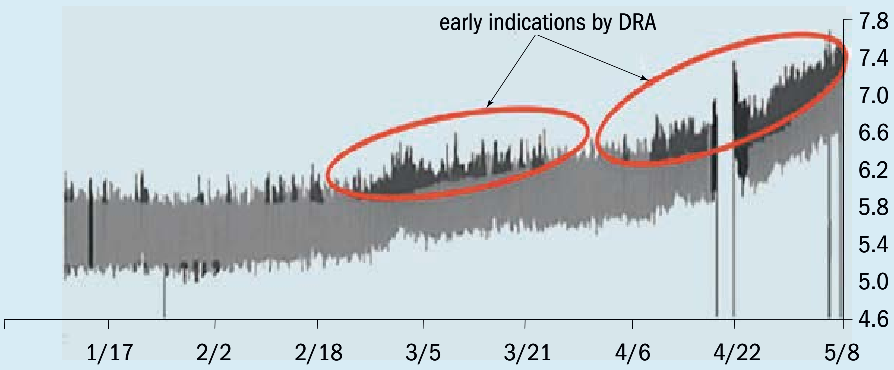


Fig 7: **120 day plot of cooling tower fan vibration**



Early identification of cooling tower fan failure

Although rotating machine vibration is one of the critical parameters monitored in the process plant, most of the increasing vibration trends are identified once the readings reach the high alarm. When the high alarm is triggered, it is only a matter of time before the process experiences a sudden failure either due to actual rotating machine failure or triggering of high-high fail-safe protection system. As a result, this allows very limited time for any intervention plan to be worked out properly and implemented.

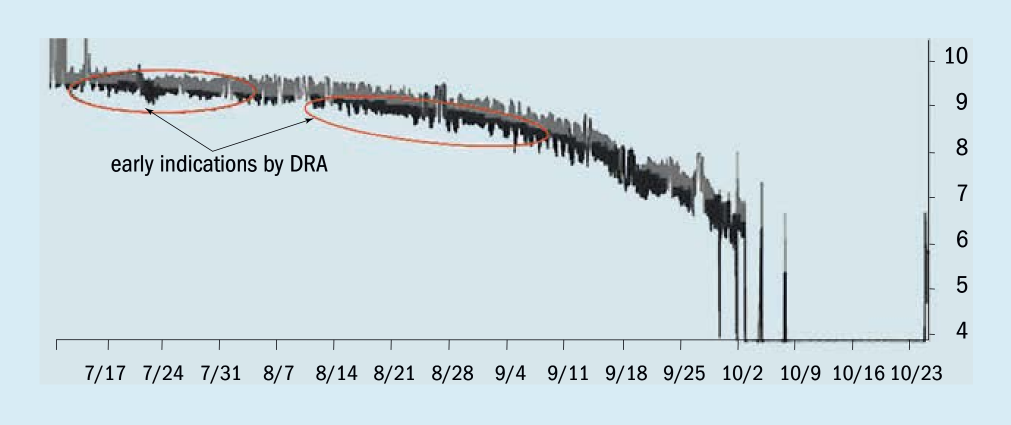
Fig. 7 shows the 120 day plot of cooling tower fan vibration. The recurring risk indications by DRA signifying gradual increasing trend in the vibration readings prompted the operations engineers to investigate these early warnings indicating potential failure of one of the cooling tower fans. This led them to plan a local shutdown for the fan for checks and rectification. At the end, this early identification of the increasing vibration allowed for better work planning and execution, subsequently reducing the fan downtime in the long run.

Early identification of product bucket elevator failure

The bucket elevator is used to transport finished product for segregation before it is sent to storage. Any failure or stoppage in this part of operations results in interruption of production. Fig. 8 shows the 120 day plot of bucket elevator displacement at the drum end. It indicates a slow decreasing trend starting in mid July.

The early indicators (by DRA) prompted the operations and maintenance teams to inspect the root cause(s) behind this problem. While waiting for the repair, adjustment was being done to ensure that the equipment can still run until the next scheduled maintenance window. DRA was also used to monitor the deterioration

Fig 8: **120 day plot of bucket elevator end drum displacement**



rate on a daily basis before the repair was done.

By knowing the problem early, action items were drawn much earlier to ensure minimal interruption to the operation. Later, it was found that the problem was caused by a damaged liner in the drum.

In general, there are many such process conditions, which are difficult to detect through the use of routine trending and visualisation techniques – that is, if they are tracked to begin with. The use of DRA technology can highlight issues at their initiation stages that are often not observable to the human eye – providing a much-needed peripheral vision to the operating team.

Conclusion

This article outlined a case study of Asean Bintulu Fertilizer (ABF) – its transformation process and steps in achieving a proactive risk management culture and workflow through the use of dynamic risk analysis technology. To demonstrate the impact of this change, four real-life use cases are presented where the engineers detected hidden operational issues early on.

After running DRA for two years, the following observations have been made by the ABF team:

- Closer co-operation exists between operations and maintenance now, as both parties have observed and worked on some important process issues in the past year.
- People are becoming more proactive as they believe that the problems are more focused now and they can identify them much earlier.
- Shifting into a proactive mindset in dealing with risks could not be achieved alone via knowledge and know-how of the subject. It had to be embedded into ABF work process to ensure continuity, sustenance and continuous improvement. DRA has played an important part in ensuring ABF's journey to achieve this goal. ■

References

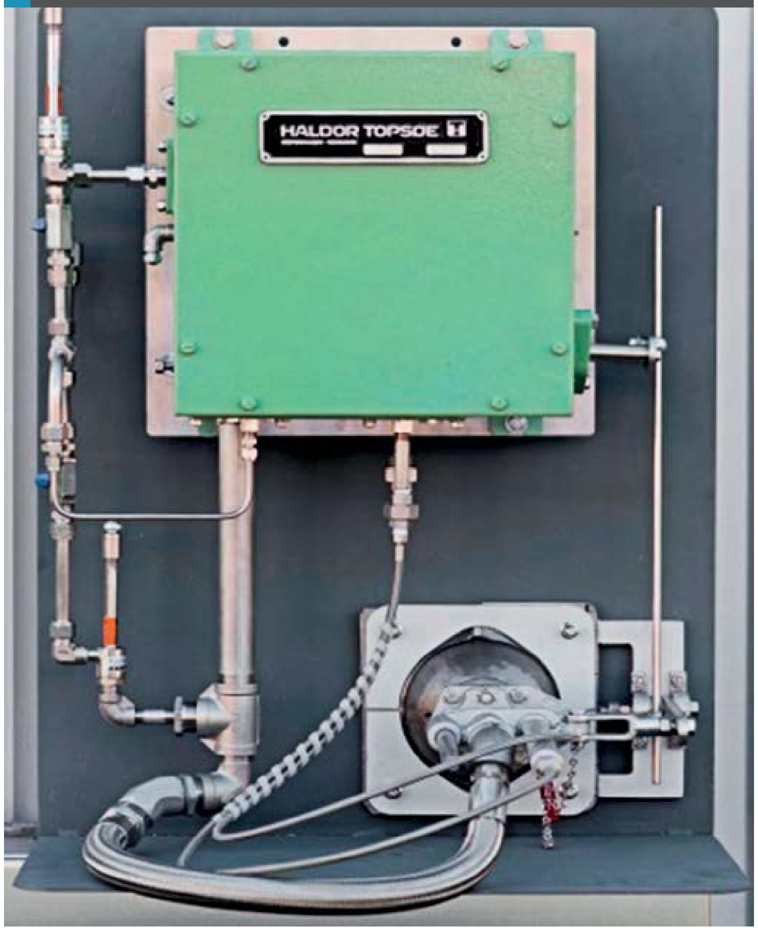
1. Kleindorfer P. R., et al.: "Accident Epidemiology and the U.S. Chemical Industry: Accident history and worst-case data from rmp*info," Risk Analysis, 23 (5), pp. 865–881 (2003).
2. Kleindorfer P., Oktem U.G., Pariyani A., and Seider W.D.: "Assessment of catastrophe risk and potential losses in industry," Computers and Chemical Engineering, 47, 85-96 (2012).
3. Pariyani A., Seider W. D., Oktem U. G., and Soroush M.: "incidents investigation and dynamic analysis of large databases in chemical plants: An FCCU case study," Ind. Eng. Chem. Res., 49, 8062-8079 (2010).
4. Phimister J. R., Oktem U. G., Kleindorfer P. R., and Kunreuther H.: "Near-miss incident management in the chemical process industry," Risk Analysis, 23(3), 445–459 (2003).
5. Pariyani A., Oktem U. G., and Grubbe D.L., "Process risk assessment uses big data," control engineering, June Issue (2013).
6. Lauridsen K., Kozine I., Markert F., Amendola A., Christou M., and Fiori M.: "Assessment of uncertainties in risk analysis of chemical establishments," Summary report on ASSURANCE project, Risk National Laboratory, Roskilde, Denmark (2002).

Acknowledgement

The authors of this article are Aslam Khan B Mohater Khan, Shahrul Anuar B Saat and A Aziz Asri B Sulaiman of Asean Bintulu Fertilizer, Sarawak, Malaysia and Ankur Pariyani, Ulku Oktem and Deborah Grubbe of Near-Miss Management LLC, Philadelphia, PA, USA.

24/7 firebox monitoring

Fig 1: **Topsoe Furnace Manager image and data acquisition units**



Topsoe Furnace Manager (TFM) is a proven personnel and process safety system for ammonia plant primary reformers, providing firebox images and data 24/7. It provides monitoring of burner flames and tube temperatures locally and remotely without human interaction with the firebox and can provide immediate economic benefits by avoiding outages, improving long term reliability, and enhancing operational excellence. **S. W. Sexton** of Haldor Topsoe describes the key features of TFM.

Global food demand is expected to increase by 15% by 2030. Ammonia and fertilizer demand will increase accordingly in response to increased food demand. Higher expectations will be placed on existing and new plants in terms of efficiency, reliability, and compliance. However, plant safety remains the highest priority to be able to achieve all other expectations.

Personnel safety is very dependent upon personal behaviour. Increased focus on personal awareness and behaviour-based safety programmes has occurred throughout industry over the past 25 years. In addition, process safety is dependent upon equipment, process design, hazard identification, and subsequent safeguards installed or implemented to mitigate the hazards' impact. These safeguards largely fall into two categories – administrative or engineered. Administrative safeguards typically require human interaction with the process, and engineered safeguards do not require human interaction. Engineered safeguards are typically considered more reliable, but costly.

The goal is to install safeguards that will economically mitigate process and equipment hazards, in an operating environment where additional demands are placed on personnel to administratively prove compliance with operating permits and a myriad of regulations.

A good safeguard provides information to drive action, or directly takes action, to mitigate the most severe hazards, and is reliable. A good safeguard is easy to use and understand. Pressure relief valves are good safeguards with audible feedback used extensively in industry to mitigate overpressure hazards, for example.

In ammonia plants, the primary reformer operation encompasses several hazards. Fire, loss of primary containment of process fluids, uncontrolled combustion, mechanical equipment failures, and process upsets are a few important hazards, or causes of hazards. Traditional hazard mitigation for primary reformer operation has required plant personnel to directly interface with the firebox to verify equipment and process status. This interaction has inherent risks, especially during potentially hazardous events. When personnel interact with a firebox to determine the status inside, they become human data collectors. It is recognised that this interaction is important, and tools have been developed to facilitate the best use of this interaction, including specialised personal protective equipment (PPE) and handheld data collectors. Even under the best of circumstances, the firebox interaction is typically a relative short duration, with only about 1,000 hours or less of data collection annually. The amount of data collected in terms of temperatures and imagery is restricted by the duration of the personnel interacting with the firebox. To increase the duration of the interaction to improve data collection an increase in exposure to hazards occurs. Therefore, ammonia producers are faced with a decision to sacrifice firebox data acquisition to reduce hazard exposure. Extrapolation and leveraging of a limited amount of firebox data is the result of the decision. This extrapolation of limited data is typically historical based, as is the operation and maintenance of the firebox. Notable firebox failures occur from gaps in historical knowledge.

Topsoe Furnace Manager (TFM) provides an alternative. TFM is an array of permanently installed image collectors acquiring images every second, 24/7 (see Fig. 1). TFM collects millions of data points annually

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 53 54 55 56 57 58 59 60 61 62 63 64

with deviation alarms, stored in an easy-to-use historian, and is remotely available to the organisation outside of the plant. TFM monitors the firebox with minimal safety risks. The virtual elimination of human-firebox interaction allows personnel to perform higher value work, such as image and data analysis, collaboration, and/or minor maintenance and turnaround planning.

TFM system

TFM is a system-of-systems including electronics, optics, data handling, data analysis, placement design, visual display, self-protection, compliance, and human-machine-interface. Image acquisition is at the heart of the system. The image collectors send the images to the data collectors, which organise, transmit, store and analyse the data. Alarm safeguards are immediately available to the plant operators, and remotely to the organisation outside of the plant supporting operations.

TFM capabilities include:

- Image collection: Over 500,000 images per image collector per year.
- Data collection: Over 50,000,000 data points per collector per year.
- Alarms: Metal temperatures and burner flame quality, such as impingement, jetting, and poor mixing.
- Benchmarked images of good examples and bad examples of burners and tubes.
- Historian: Time and date stamped images with data.
- Remote access to images and data.
- Wireless computer interface with firebox.
- 24/7 persistence of the entire system.
- Self-protection for reliability.

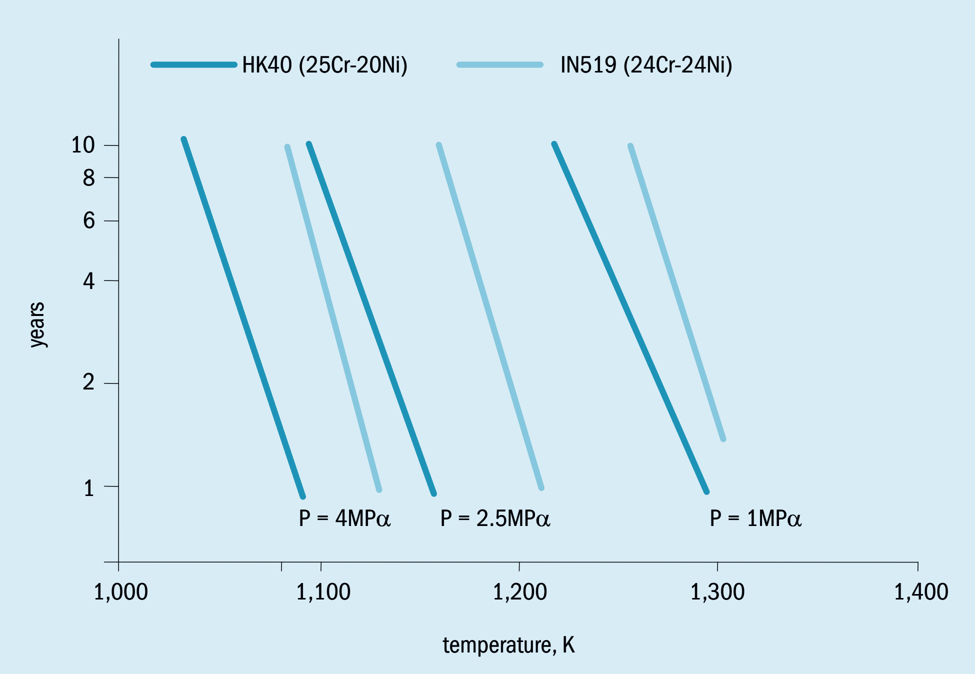
TFM process safety benefits

Process safety management mandates certain important areas of focus for industrial plant operations. Process safety represents best practice, and is a compliance requirement. TFM provides critical information for several process safety areas of focus.

Mechanical integrity and asset protection

Asset protection is a very high priority in ammonia plant operations. Inside the firebox, catalyst tubes experience "creep." Creep is a metallurgical deformation with dependence upon stress, time-in-service and temperature-in-service of metals exposed to high operating temperatures (Fig. 2). Historically, reformer tube creep progression has been measured by reformer tube diameter growth over time, with measurements recorded during major firebox outages, such as during a catalyst change. These spot creep measurements are good indicators of remaining life, excluding consideration of significant events (power outages, start-ups, shutdowns, process upsets) which add a higher level of stress in a short period of time. Essentially, current creep prediction is calendar-based for an entire set of reformer tubes. Autopsy of reformer tubes typically indicates that not all tubes experience the same creep progression, and tube sections can also progress differently. This variation in creep progression for tubes with identical time-in-service is the result of variations in temperature-in-service (Fig. 3), excluding local stress contributors. Temperature-in-service variations result from burner and combustion variations, combined with process variations. TFM provides images and temperature data to correlate combustion and process variations within the firebox. The resulting analysis and correlation provides specific mechanical integrity information that can be acted upon by mechanical integrity and process subject matter experts (SMEs) to reduce variation and improve overall tube mechanical integrity. TFM imagery and data also drive action on other aspects of firebox components, such as burner failure, refractory failure and structural compromise.

Fig 2: Example tube life and temperature correlations. A 10K temperature increase can decrease tube life by 30%



Asset protection economics

TFM pays for itself in an outage of less than a week if the outage is avoided utilising TFM's temperature alarm function, and burner quality information; based on a TFM cost of $1,000,000, and $200/t ammonia profit margin for a 1,000 t/d plant. For example, outage avoidance with TFM is the result of literally seeing flame impingement causing hot catalyst tubes, and making corrective actions before irreversible damage and an incident occurs. Additionally, if an outage can be avoided due to new operators' misunderstanding of firebox process conditions, such as upsets caused by draft swings, fuel swings, rate changes, or even weather disturbances, TFM pays for itself quickly. TFM enables new operators to see cause-and-effect as it happens in the firebox.

TFM's asset protection capabilities are especially useful on start-ups and shutdowns of the primary reformer, and TFM is working during normal operation (98+% of the time) when flame scanners are not active by design once auto ignition temperature is reached. Although unusual, loss of flame does occur at normal operating temperatures, and is routinely observed on furnaces where TFM has been installed. Without alarms on these flame-outs, they go undetected.

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 53 54 55 56 57 58 59 60 61 62 63 64

Administrative safeguard and alarm history

TFM's alarm and historian capabilities also support the overall intent of process safety management by providing immediate feedback for operational mitigation, and historical capture of important equipment status. This duality of immediate information and historical data capture enables safe day-to-day operations, and continuous improvement through engineering over time.

Furnace burner balancing

TFM will provide the data and the tools to effectively balance firing to minimise the temperature variation across each row of tubes, as well as, throughout the furnace.

Based on previous reformer balancing studies, fuel gas consumption improvements of 1-2% are possible at the same production rate with savings estimated up to $100,000 per year. Burner balancing may provide a production increase excluding other bottlenecks. Balancing tube skin temperatures will result in longer tube and catalyst lives while significantly reducing the risk of tube failures and costly downtime. Expected efficiency improvements pay for TFM during a reformer catalyst life cycle.

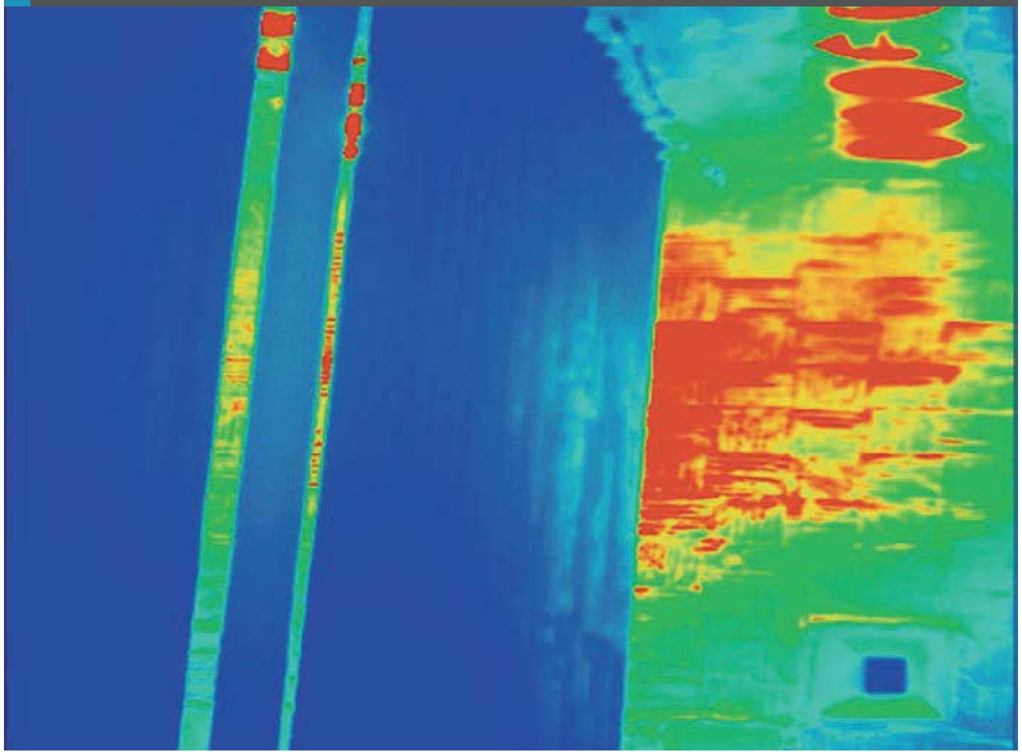
Reliability economics

TFM's burner balancing also improves reliability that results in savings over time due to longer catalyst tube life. TFM is paid for in a tube harvesting protocol based on creep measurements when about 10% of the reformer tubes avoid replacement at the first outage. 100% of the tubes in a world scale reformer with TFM installed documented creep of less than 1% at mid-life (about 45,000 hours) at normal operating temperatures.

Incident investigation

Sudden incidents (such as power failures) impact on firebox component integrity have been difficult to correlate. Overheating events during start-up and shutdown have been difficult to capture without increased exposure of personnel to firebox conditions. Subjectivity permeates most firebox incident investigations resulting in potentially inaccurate conclusions. TFM images and stored data show exactly when an event began, and the consequences of that initial event.

Fig 3: **Firebox colour coded temperatures**



TFM information is readily available to the entire incident investigation team, even remotely, in a matter of minutes so that the root-cause-analysis can begin quickly, and the next incident can be avoided.

Training

Training of new and existing personnel on firebox operations has traditionally involved a steady-state model with a minimal amount of information available regarding firebox behaviour during transitions. With reformers, there are several dynamic scenarios that impact burner operation and catalyst tube temperatures, especially during transitions such as start-up and shutdown. TFM captures images with data to provide actual transient information that can be implemented in training, including dynamic training simulators. Additionally, training benchmarks are captured, and can be inserted into training documentation to establish best practices.

Process hazard analysis

Mitigation of firebox overheating scenarios and consequences typically rely on safeguards such as fuel pressure, firebox draft, and spot process temperatures. These process measurements represent historical safeguards based on the capability of prior furnace process measurement technology. TFM provides additional firebox process measurements. Actual flame intensity and flame shape; and actual catalyst tube temperatures over a large surface area are now available to utilise as administrative safeguards without reliance on personnel directly interacting with the firebox.

Standard operating procedures (SOPs)

SOPs traditionally have relied upon historical operational information collected and documented based on past best practices. For firebox operations, SOPs typically require a person to physically inspect the firebox condition on a recommended frequency. This inspection frequency can be unrealistic, especially during start-up and shutdown when other operational priorities take precedence. TFM provides continuous firebox inspection, and image targets with data targets can be captured and documented to provide new best practice examples. These examples can be embedded within the SOPs, whether or not electronic, and provide direct comparison with real-time images and data captured by TFM during operation.

Compliance audits

Self-auditing of firebox compliance has traditionally relied upon written tube temperature and firebox inspection reports generated by operations personnel. The fundamental basis of the measurements is difficult to correlate. For example, tube temperature measurements are typically reliant upon a map generated by engineering or operations management specifying locations on the tubes and locations of the person performing the measurement, with specification of the measurement device (camera), and direction to capture results manually on a log sheet. This series of information handoffs is vulnerable to inaccuracy, even with the best efforts of trained personnel. TFM information is captured and stored with locations, device, images and data specifications held constant. TFM captures firebox burner imagery and data, which has historically been absent. Better audits result from better information and data.

Employee participation

Employee participation in safety regarding fireboxes has typically involved PPE specification, SOPs for firebox interaction, permitting, lock-out-tag-out protocol, and other best practices heavily weighted in personnel safety. Process safety considerations typically have involved enforcement of SOPs and safety system calibrations. Process limits and trip points may not be well understood. Actual process safety limits regarding overheating of reformer tubes and poor burner performance resulting in flame impingement and localised tube overheating, afterburning, or flameouts are not fully considered due to lack of information. TFM provides that missing process information necessary for enhanced employee participation and understanding of firebox process safety.

Pre-start-up safety reviews (PSSRs)

Firebox PSSRs typically focus on a review of process setpoints, process and instrumentation diagrams (P&ID's), safety system functionality, hazard review, and process transitions over an expected timeline. Human interaction with the firebox to collect data and interpret firebox condition during a period of constant change over at least 12 hours during a reformer start-up is difficult to evaluate in a PSSR, especially for key personnel. TFM reduces or eliminates the level of physical interaction required during start-up, and distributes the human interpretation element to a group utilising TFM remote access capabilities. The natural intent of the PSSR to involve a group review with collaboration is enhanced and supported by TFM.

Additional mechanical integrity information

Reformer firebox mechanical integrity information has historically consisted of design specifications, mechanical drawings, P&IDs, operational limits, and general operational guidelines provided by the technology supplier. TFM provides actual operating data in the form of images with catalyst tube metal temperatures and burner intensity and flame patterns. Combustion-side operational information can be correlated with process information to bridge the knowledge gap. Process and combustion upsets can be correlated with TFM information. SOPs can be tailored to specific furnaces based on their operational fingerprint. Training, including simulators, can be tailored to specific furnaces based on their actual behaviour. A deeper understanding of the interaction between combustion and process side heat exchange is possible with analysis of TFM images and data.

Personnel safety

Evaluations, recommendations, and programmes on industrial plant behaviour improvement have become a big business for behaviour professionals. Recognition of the importance of the human side of overall industrial performance is long standing. TFM mitigates many of the human issues associated with furnace operation. TFM improves individual performance through behavioural safety improvements.

Firebox interaction

TFM reduces, or potentially eliminates, direct personnel interaction with the firebox. Even when direct human interaction is required, it can be well planned, permitted with job safety analysis (JSA) evaluation, directed with specific information requirements identified, and minimised in terms of radiation exposure. In actual field use of TFM, furnace operations have continued with small process problems supported with strict enforcement of limited personnel interaction with the firebox. This enforcement included access restriction to the firebox upper deck during the time period the process issue persisted. By restricting personnel access to the firebox, and enabling a safe operation until proper materials were received, business risk was also reduced. The capability to view the problem and continuously compare its progression remotely provided transparency and confidence to all personnel.

Firebox data collection

TFM reduces frustration resulting from repeated firebox, visual data collection requests by non-plant colleagues. Collaboration is a great operational lever, and is highly valued in today's business environment. When data is remotely available, engineers can engineer, planners can plan, and managers can manage. When data is not remotely available, and with today's communication channels, such as cell phones, firebox information requests can overload those residing in closest proximity to the firebox. Often the task of firebox data collection falls on the furnace operators, or junior plant furnace image engineers. This can be a good training activity, but it also can lead to very high levels of frustration from those collecting the data. This frustration can lead to unpredictable behaviours in a plant environment, which is inherently dangerous, complex and frustrating by nature. There is high value by not adding any degree of frustration to a plant operating environment. TFM provides images and data remotely regarding firebox status. Requests for firebox information can then be directed toward TFM functionality rather than human firebox data collection.

Furnace stair climbing

Although arguably good for health, physical exertion and stair climbing, especially on modern supersized furnaces, is difficult. The design of many modern-day furnaces exasperates the exertion requirement. The furnaces are larger, taller, and more complex than in the past. The exertion required to climb up and down a large furnace is better spent ensuring that TFM remains on-station collecting important firebox images and data rather than looking through many peep doors and manually recording data.

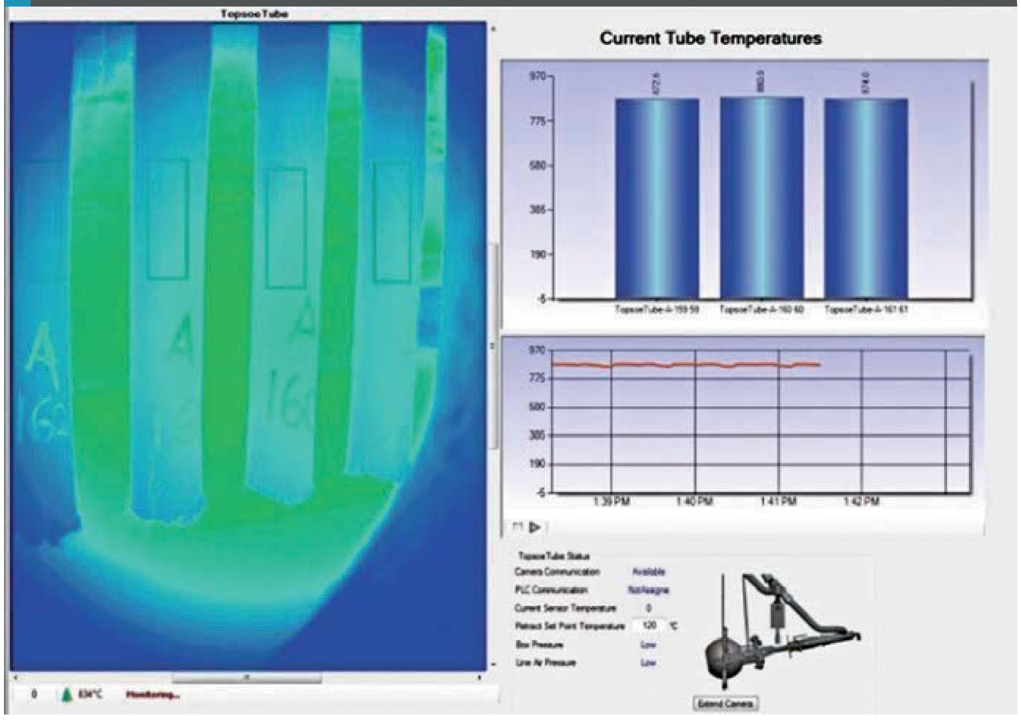
Furnace problems

TFM reduces confusion and anxiety during periods of time with furnace issues. Problems can be shared within the organisation to make plans and provide guidance quickly. Furnace issues are nearly inevitable due to the nature of the operation. The ability to handle any problem is made easier with information. Without information, confusion, anxiety, and frustration build up to an unacceptable level. The remote viewing capability of TFM, supported by the capture of images and data stored in the historian, enable communications, planning and organisational coordination during periods of furnace problems.

Furnace guidelines and documentation

TFM reduces confusion regarding linkage between hazard reviews, firebox SOPs, firebox critical safety systems, and actual operation. It is difficult and time consuming to ‘connect-the-dots’ between all sources of required process safety information. It is especially difficult to link process information if fundamental process parameters are not available. Reformer furnace tube surface area is one of the largest heat transfer surfaces in the ammonia plant. It is also one of the least monitored for data due to the harsh operating environment. TFM’s non-contact temperature data and image acquisition provides the information needed to link process information so that it makes sense and isn’t confusing. (Fig. 4) This is especially important in fundamentally understanding critical safety system intent.

Fig 4: **Reformer tube image with data**



KPI attainment

TFM provides process documentation resulting in attainment of production key performance indicators (KPIs) while maintaining firebox components within their safe operating window. Ideally, all organisational KPIs are perfectly aligned and in support of an overall strategy that moves the business forward. In reality, there are typically some natural KPI conflicts, such as cost control and cost of repairs. These conflicts require human collaboration. Especially in the case of furnaces representing high cost operation, conflicting KPIs can lead directly to conflict. The conflict is best addressed with data and not emotion. TFM provides the data so that a collaborative decision-making process can take place.

Personnel risk exposure

TFM supports remote location of personnel with reduced risk exposure frequency. For example, a major, instantaneous reformer piping incident occurred on a reformer with TFM installed that resulted in no injuries because personnel were remotely located away from the furnace. Some older, existing plants were built with a lower emphasis on risk and exposure to personnel. Modern risk evaluations, including QRAs, actually quantify personnel exposure and risk.

The quantified risk matrix considers work patterns, which are a function of equipment inspection frequencies, or “rounds.” Furnace rounds have typically been historically set by previous habits and patterns established many years ago. With TFM, the furnace rounds are not required on the same frequency as historically understood to be required. Just as the industry trend has been to move personnel away from operations unless necessary, personnel within the plant itself are at less risk when exposed less frequently to the furnace firebox.

Burner evaluations

TFM eliminates frustration associated with human burner evaluations. Modern day, low NOx, industrial furnace burners are difficult to see with the human eye. When fired on a mixed fuel consisting of a significant amount of hydrogen, the low NOx burners develop a flame that cannot truly be evaluated with the human eye. TFM’s capability to monitor flames which the human eye cannot see, and to provide alarms when the flame is underperforming, eliminates the need for personnel to visually decipher flame quality. TFM provides a flame intensity measurement which is charted and graphed continuously, so that the impact of rate changes and fuel/air changes is captured. When the flame is not behaving correctly, TFM will alarm to notify the organisation that there is a burner issue. Sunburnt eyes from looking inside a firebox at flames too long are not necessary with TFM. Eliminating a source of physical pain is a very tangible improvement for personnel. TFM encourages burner tuning. Proper burner operation contributes directly to proper furnace operation. With TFM’s ability to adjust view angles and regions-of-view, burner adjustments and burner performance improve with increased levels of understanding. Additionally, TFM captures the images to benchmark exactly how burners should appear during various process scenarios.

Weather

Operations personnel monitoring and managing large reformers face interesting and challenging scenarios involving weather events. Rain, snow, heat, cold, and wind all impact the ability to physically monitor a reformer. Weather compounds any difficulties associated with specialised PPE that is typically required for furnace interaction. Face shields and fire retardant clothing can be cumbersome during normal activities such as stair climbing. Weather events make the situation even more difficult, which can lead to personal safety events, such as tripping or falling. Importantly, serious furnace monitoring needs to occur

1 47 2 48 3 49 4 50 5 51 6 52 7 53 8 54 9 55 10 56 11 57 12 58 13 59 14 60 15 61 16 62 17 63 18 64 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

Fig 5: **Time and date stamped image**

during a weather event. Critical management decisions to continue operation during weather events depend on operations personnel climbing stairs and looking into the reformer firebox. TFM can eliminate the need, or greatly reduce the frequency, of physical human reformer inspections during weather events. This capability provides time for higher value plant activities while reducing personal safety risks.

Permitting

LOTO (lockout-tagout), confined space, and vessel entry are permitted activities during furnace turnarounds (TARs) and outages. These activities represent some of the most complex job permitting activities in an industrial plant. Furnace LOTO is a difficult process due to the process energy isolation and combustion energy isolation required. Air quality inside a firebox can also become contaminated if the firebox is part of a larger industrial complex. Continuous air monitoring could be required during firebox work on a TAR. And, confined space/vessel entry procedures are typically required during firebox work. Elevated work from scaffolding, and overhead hazards from crane equipment are also typically present during firebox work. Considering that firebox work during TARs is also an infrequent activity, the more information and time to plan this activity inherently makes it safer to execute. Visual images of the firebox from TFM are helpful to create understanding of where and how work will be performed in the firebox.

Process control schemes

TFM provides data to establish actual equipment-operating-envelopes for tubes and burners. TFM data can be integrated into DCS. Tube temperatures and burner quality can be mapped and characterised for use in advanced firebox analysis.

Operational excellence

Support groups collaborate using the same TFM images and data as reference for discussions. Historical information is available "on demand" without relying on the operations group for retrieval. Compliance data is available at all times. Subject matter experts have remote access to furnace operations with time-and-date stamped images (Fig. 5).

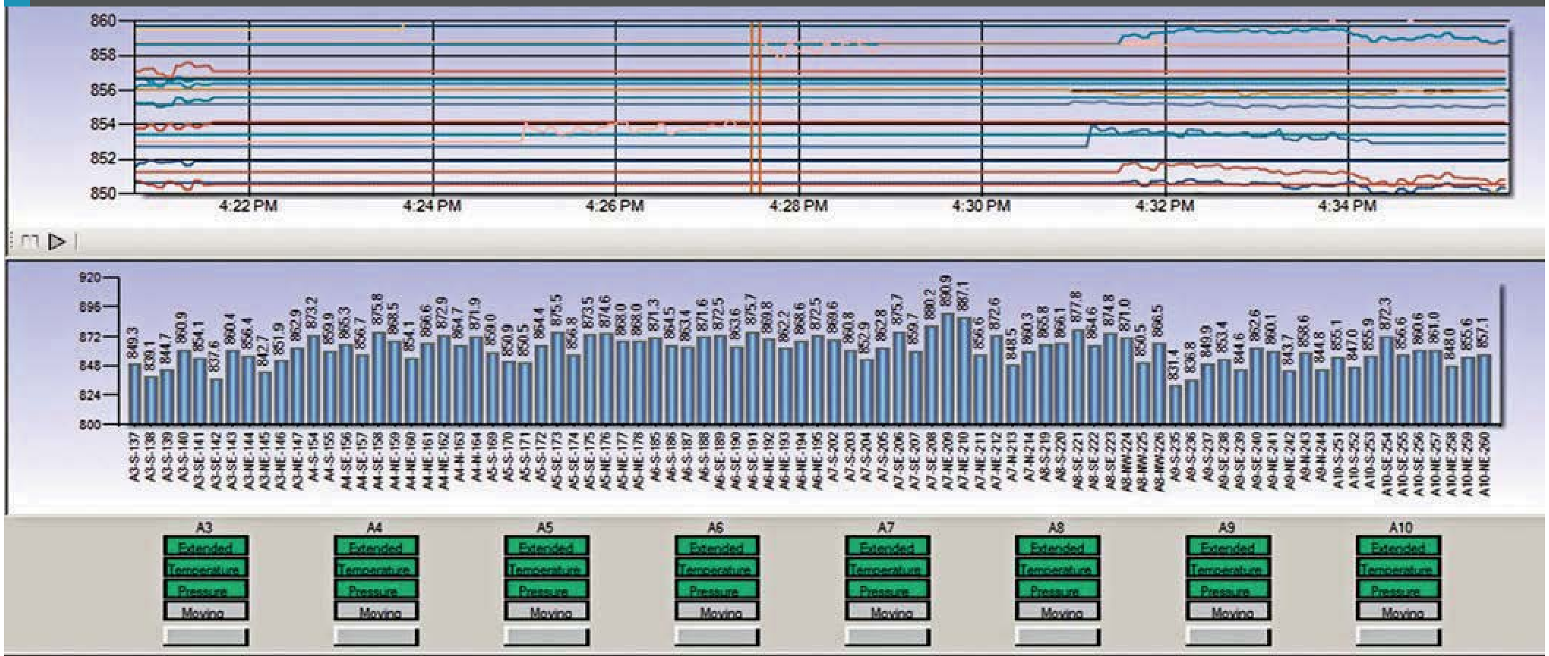
Furnace lifecycle

Furnace equipment performance and repair history are captured with time and date stamped images. Temperature data is correlated with equipment performance, metallurgical analysis and repairs. Visual images are available for operations and reliability team training. Historical tube and burner performance is captured with images and data (Fig. 6).

References

1. FAO United Nations, "World Agriculture Towards 2030/2050" (June 2012)
2. J.R. Rostrup-Nielsen, "Catalytic Steam Reforming", (1984).

Fig 6: **Tube temperature charts and graphs**



Make more from less

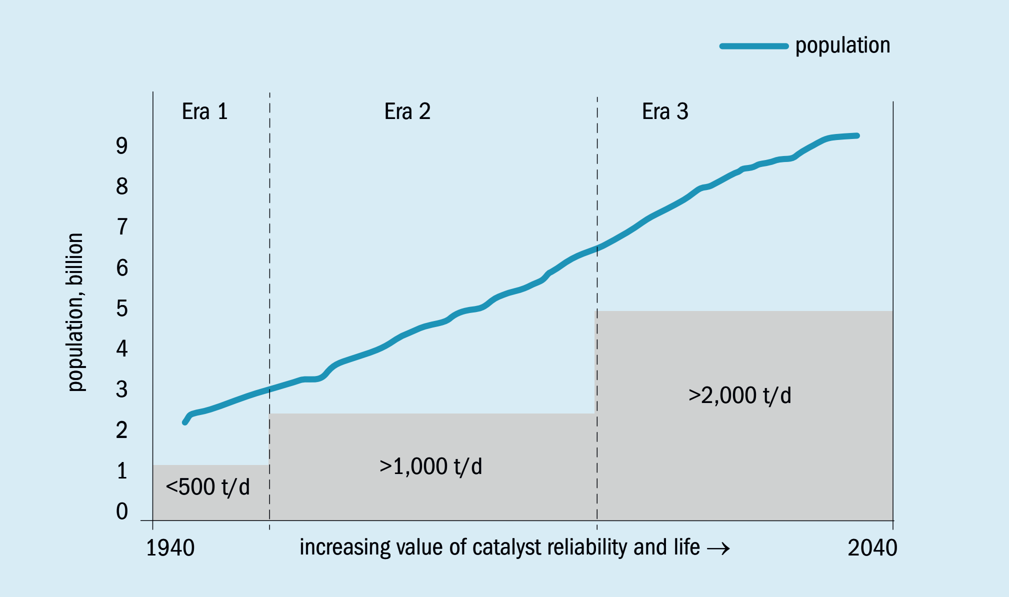
Catalyst changes in the ammonia process offer an ideal opportunity to reduce pressure drop and/or energy requirements with the minimum of additional expense. **M. Cousins** and **J. Brightling** of Johnson Matthey review the fundamentals that need to be considered and look at case studies showing how the latest technologies and plant operation philosophies can be utilised to make more from less.

Over the last 100 years, the nitrogen fertilizer industry based on ammonia production has grown massively. Drivers behind this growth have been, and remain, increasing global population coupled with increased plant size to achieve better economies of scale. This has created demand for increased capacity and better reliability (Fig. 1).

Since the first industrial plant operated by BASF in 1913, the industry has progressed through different eras of growth and development.

- **Era 1:** <500 t/d operated from the 1920s, with some still operational today
- **Era 2:** the advent of 1,000 t/d single stream plants of the 1960s, and
- **Era 3:** >2000 t/d with leading-edge 3,300 t/d pioneered by thyssenkrupp Industrial Solutions (tkIS, formerly Uhde).

Fig 1: **Population growth vs increasing ammonia capacity with time**



Era 1 saw plants limited by the ability to boost the pressure inlet of the ammonia loop, which meant the process capacity up to the early 1960s was limited to around 600 t/d. The limitation was the reciprocating compressors that were used to provide high pressure syngas to the loop, and circulate it. The image to the left of Fig. 2 shows the machinery in the ICI compressor and circulator house taken in 1927.

Era 2 saw this limit overcome by the use of centrifugal compressors, which the majority of the ammonia plants utilise today. The image to the right of Fig. 2 shows a picture of a modern centrifugal compressor. The introduction of this type of machine, by M. W. Kellogg, saw the creation of the 1,000 t/d ammonia plant. This design was then widely adopted globally and there are still many operating examples of this type of flowsheet, making ammonia in every region of the globe today. Many having been improved, introducing enhancements to capacity and energy to the point where many of these plants are still energy efficient and able to produce well above the original name plate design.

Era 3 has seen the average size of new plant builds exceed 2,000 t/d by having low energy consumption typically ~6.7GCal/tonne. The largest plants, pioneered by tkIS in partnership with Johnson Matthey are >3,000 t/d capacity. This new technology scale has been well proven and established utilising Johnson Matthey's optimised catalyst solutions, demonstrated by the examples given in Table 1.

A requirement for any plant design will always be to meet the scope of the design and minimise the cost of the plant. But, once a plant is operational, an operator will seek improvements, to increase ammonia make or greater efficiencies for the maximum return on their investment.

These different considerations are illustrated in Table 2.

This means plant operators and plant designers must embrace technology developments, to optimise the capital and operating costs of the process.

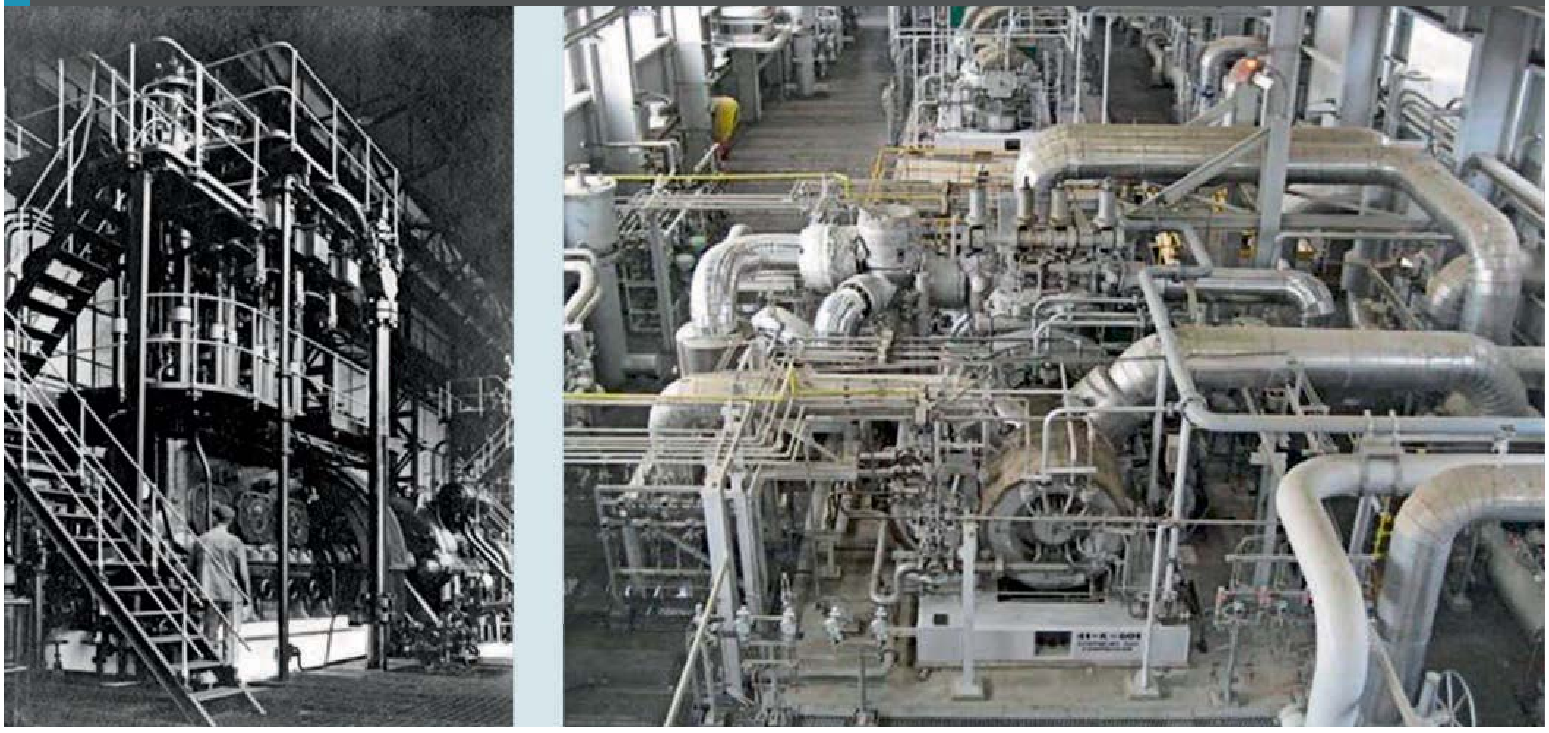
An optimised catalyst design, through the initial or a routine catalyst change, can help to achieve these goals by:

- **Lowering pressure drop:** One option is to increase the pressure at the inlet of the syngas compressor by decreasing the pressure drop in the front section of the process. The potential benefits of this will vary from plant to plant. It can provide an increase in energy efficiency (in the compression of the syngas), or help overcome other limits in the plant, such as air compressor or CO_2 removal limits.
- **Increased activity at lower temperatures and/or better heat transfer:** An operator can consider using catalyst materials with higher activity or better heat transfer to lower the energy demand they require to operate effectively.

Optimised catalyst design

Each duty presents an opportunity where catalyst design can be used to improve operation. However, catalyst design must

Fig 2: **ICI compressor house installed in 1927 (left) and modern gas turbine compressor (right)**



PICTURE COURTESY OF TKIS (UHDE)

Table 1: **TKIS/Johnson Matthey ammonia plants in Era 3 with capacities >3,000 t/d**

Plant	Location	Capacity	Start-up
Saudi Arabian Fertilizer Company, SAFCO 4	Al Jubail, KSA	3,300 t/d	2006
Saudi Arabian Mining Company, Ma'aden	Raz Az Zwor, KSA	3,300 t/d	2011
CF Industries, Donaldsonville, Ammonia 6	Donaldsonville, LA, USA	3,300 t/d	2016
Saudi Arabian Mining Company, Ma'aden 2	Raz Az Zwor, KSA	3,300 t/d	2016

Table 2: **Considerations of different parties when ammonia plants are designed or modified**

Parameters within design scope	Ammonia plant designer	Operator – focused on efficiency	Operator – focused on ammonia make
Ammonia make	To a design	Secondary focus	High as possible
Operating costs	Low as possible within budget limitations	Low as possible	Secondary focus
Capital costs	Low as possible	Optimise return on investment	Optimise return on investment

take account of all the plant flowsheet requirements, not just a single parameter – such as lowering pressure drop. To achieve this, the catalyst design process must integrate knowledge and technology over three scales, as illustrated in Fig. 3.

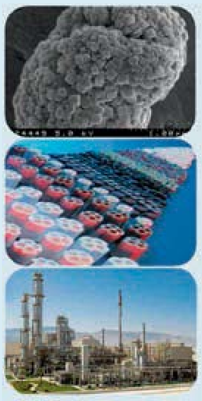
For each duty, the different operating conditions and requirements demand a different balance of catalyst design parameters, leading to the visible differences between the pellets, extrudates and granules used. While not as visible, the active surface of each material also differs hugely to best suit the needs of each duty. There are many parameters that can be considered as part of a catalyst design process. Some, for example robustness and activity, are applicable to all duties.

The rate of deactivation of a catalyst needs to be minimised and predictable over its lifetime to meet the requirement of the overall flowsheet, and so that catalyst replacements can be made in a pre-planned and organised manner. Table 3 provides an outline assessment of key catalyst design parameters and their relative importance to each duty in the flowsheet.

Poisons resistance

The need for poisons resistance is mitigated by the vital role that the upstream purification system plays in protecting the

Fig 3: **Three scales of optimisation that must be considered in the design of a new catalyst**



Micro scale: optimal atomic surface to drive the ammonia process

Pellet scale: optimal shape/form of the catalyst's technology

Flowsheet scale: integration across the flowsheet to maximise the overall benefit

1 47 2 48 3 49 4 50 5 51 6 52 7 53 8 54 9 55 10 56 11 57 12 58 13 59 14 60 15 61 16 62 17 63 18 64 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

downstream plant catalysts. The catalysts and absorbents used need to have a resistance to the poisons they are targeted to remove, in terms of their integrity and stability at the end of life when they are fully laden with the target impurity. It is also important that they are as inert as possible to other contaminants to which they are exposed.

It is a significant advantage for the primary reformer catalyst to have the ability to recover from upsets where poisons may be present. This is achieved by using a material composition able to tolerate an aggressive steaming process, to drive poisons (typically sulphur) off the catalyst surface and allow it to recover activity. The calcium aluminate support and exceptional in-service strength of the KATALCO$_{JM}$ QUADRALOBE™ range mean that it can readily undergo this treatment if required.

Chlorides and sulphur can also enter the process through the air intake to the secondary reformer. The temperature of the secondary reformer means these impurities have little impact here, as they can pass over the secondary reforming catalyst in the gas phase. The material composition of the HTS catalyst and its operating temperature ensure there is also limited impact on that catalyst. However the catalyst composition of LTS catalyst and its temperature of operation mean that poisoning is the primary deactivation mechanism for this catalyst. KATALCO$_{JM}$ 83-Series provides a self-guarding mechanism that means the bulk of the catalyst bed is protected. The benefit of this system can be taken in one of two ways. The entire vessel can be charged with active LTS catalyst that will extend the campaign length. Alternatively, the volume of charged catalyst can be minimised if there is not a driver to extend the campaign length, so reducing the pressure drop when compared with LTS catalysts that require a guard layer.

Table 3: **Key catalyst design parameters and relative importance to flowsheet duty**

	Poisons resistance	Heat transfer	Pore diffusion	Film diffusion	Pressure drop
Purification	✓✓✓	✓	✓✓✓		✓
Primary reforming	✓✓	✓✓✓		✓✓✓	✓✓✓
Secondary reforming	✓	✓		✓✓✓	✓✓✓
HTS	✓	✓	✓✓✓	✓	✓✓✓
LTS	✓✓✓	✓	✓✓✓		✓✓✓
Methanation	✓	✓	✓✓✓		✓

Heat transfer

This is most important in the primary reformer as the reaction is strongly endothermic, so it requires an external heat source to drive the desired forward reaction. To achieve this, the catalyst is loaded into tubes that are externally fired to provide the heat (energy) that the reaction requires.

The reformer tubes and catalyst must be able to transfer heat from the external source, the burners, to the tube surface through the tube wall and into the catalyst bed where the reaction is taking place on the catalyst surface.

It is vitally important to optimise the catalysts to aid heat transfer via the packing pattern that it forms when it is loaded into the reformer tube. The number of contact points between catalyst pellets and the tube is key, both to act as direct point of heat transfer and also to disturb the gas film down the inside surface of the tube, to invoke mixing and so move heat into the tube. Johnson Matthey has developed the latest computational modelling tools in house to ensure a leading edge capability to apply and develop these technologies. Fig. 4 illustrates heat passing from flue gas to process gas through the tube wall and two sets of boundary layers. It also shows a result from computational

Fig 4: **Heat transfer process from flue gas to process gas**

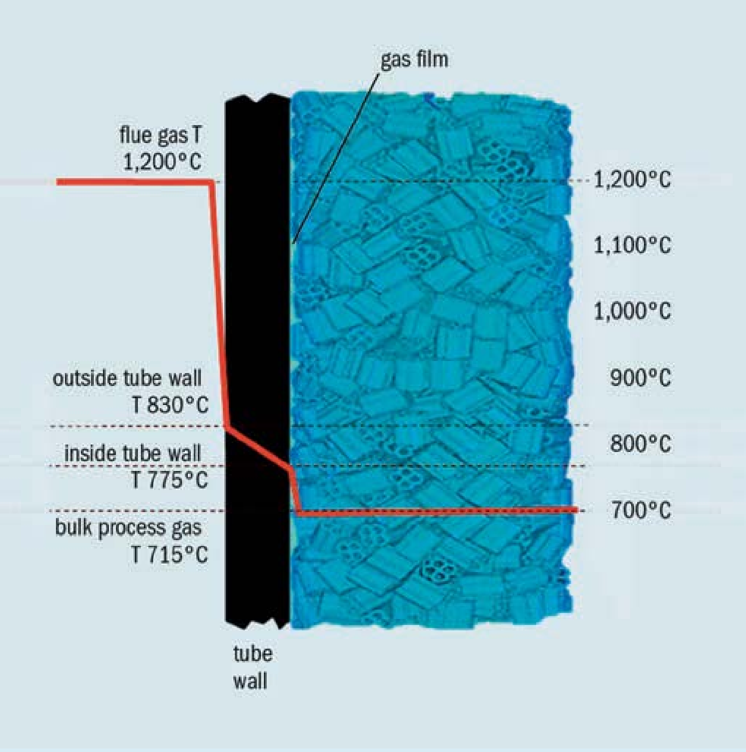
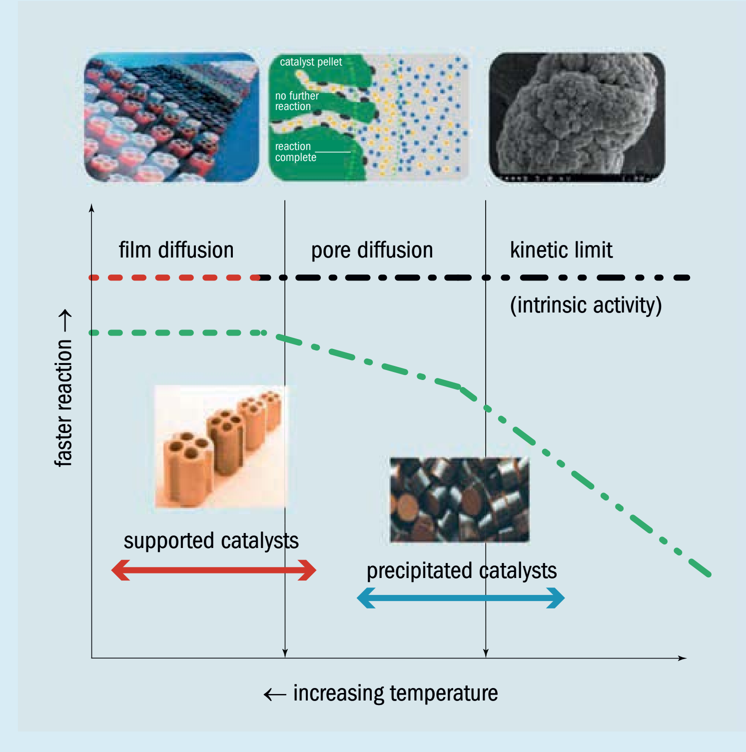


Fig 5: **Arrhenius plot of rate increase vs temperature**



modelling of the packing efficiency for the KATALCO$_{JM}$ QUADRALOBE material inside a tube, this high packing efficiency in the tube has a direct impact on the optimisation of the heat transfer.

This ability to model packing patterns coupled with the use of computational fluid dynamics (CFD), and Johnson Matthey's proprietary reformer modelling tool, REFORM, enables Johnson Matthey to offer optimised solutions. These tools are also used to develop the next generation of catalysts for this highly stressed duty to overcome the challenges of heat transfer, as well as the other key parameters.

Activity, diffusion and pressure drop optimisation

These parameters are highly interlinked. This can be exemplified by the general statements made below:

- "To reduce the pressure drop over a catalyst bed a larger size of catalyst can be used".
- "Using larger size of catalyst reduces the observed activity, because the geometric surface area (GSA) is reduced and equivalent sphere diameter increased making it harder for the reactants to access the centre of catalyst".
- "Diffusion limitations can be overcome by generating a more open pore network, however the risk in doing this is that it weakens the material making it less robust".

Activity and diffusion

The reason for using a catalyst is to increase the rate at which reactants are transformed to products. The rate limitation can occur in one of three ways as depicted in Fig. 5, which shows a trend of increasing rate with temperature. The intrinsic rate is a function of temperature, as described by the Arrhenius expression.

$$k = A\ e^{(-Ea/RT)}$$

Where k is the rate constant, A is the pre exponential term, Ea is the activation energy, R is the molar gas constant and T is the temperature. The effect of temperature can be characterised into three regions.

Kinetic limit – this is where pore and film diffusion have a limited effect and the rate limitation is the number of available active sites. The number of active sites can be increased by increasing metal loading or the packing efficiency of the material. If the metal loading is increased, the metal dispersion must be maintained to retain the same activity gain for each increase in metal loading that is considered.

Pore diffusion limit – this is where the access and egress to and from the active sites in the core of the catalyst limits the rate of reaction. Increasing the GSA and minimising the path length to the centre of the catalyst, (equivalent sphere diameter), will both help. Therefore, using smaller and/or more complex catalyst shapes with a more open pore structure will help to meet these requirements.

Film diffusion – this is when diffusion through a gas film on the surface of the pellet, limits the observed activity. The limitation can be combated by using smaller material, or material that has a shape that provides an increased GSA to increase the surface area of the gas film.

At lower temperatures, where there are kinetic limitations, it is beneficial to add more metal to increase the active surface area. The delivery of this is possible through precipitation, where the precipitate itself provides much of the structure and so allows for a greater metal loading to be achieved.

At moderate temperatures, it is beneficial to create a more open internal pore structure to combat pore diffusion limits. Precipitation can still often be used to develop the pore structure which is created through precipitation, thermal processing and reduction. These processing steps can enhance the pore network around the metal particles so improving the catalyst formulation.

Once an active and stable catalyst surface is available, the question is how to present that surface to the process. Minimising pore diffusion by providing an open pore network is advantageous, as long as the material strength is retained. Using smaller pellets to minimise the path length from the outer surface to the centre of the pellet is another option, but this alone will increase pressure drop. This is why it becomes beneficial to look at optimising the pellet shape. When done correctly this can:

- increase activity (rate);
- decrease pressure drop;
- maintain or better the robustness of the material.

At higher temperatures the drive to overcome severe diffusion limits drives the catalyst designer to form more complex shapes, whilst maintaining the strength and robustness of the material.

To understand the value of shape optimisation it is important to understand the value of lowering the pressure drop.

Pressure drop

Increased catalyst pressure drop lowers the suction pressure of the synthesis gas compressor. This can impact on both plant rate and plant efficiency. Based on the knowledge of their own limitations, it is very common for plant operators to develop their own rules of thumb as to the benefit (or cost) of lower (or higher) pressure drop.

For example, common rule of thumbs seen have been:

- "Reducing 1 psi of pressure drop downstream of the secondary reformer saves about US$ 10,000 per year in terms of improved efficiency (US$2 gas, 1,500 t/d plant)".
- "Decreasing the pressure drop by 1.75 psi enables the plant to achieve 0.5% increased output".

Knowing the value of pressure drop for a particular plant means the value of different pressure drop scenarios can be calculated to help determine the optimum loaded catalyst volumes and best catalyst sizes to use.

Pressure drop profile

Pressure drop profiles over the front end of two different ammonia plants (with different flowsheets) are shown in Fig. 6. Although each profile is different, it is possible to make some generalisations. 70-80% of the pressure drop over the front section of the flowsheet is a result of pipe runs and equipment. 20-30% of the pressure drop is a result of installed catalyst volumes. Of this, the majority, 40-50%, is generally over the primary reforming catalyst, ca. 25% over the shift beds and ca. 25%, over the rest, namely purification, secondary reforming and methanation.

Process limits

Each plant will have its own specific limitation. These may include pressure relief limits or the capability of the air or syngas compressor to provide sufficient flow to satisfy the process requirement. If the operating limit is CO_2 removal, then operating the absorber at higher pressure can also be beneficial in some cases.

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 53 54 55 56 57 58 59 60 61 62 63 64

Johnson Matthey catalyst solutions

Johnson Matthey is able to provide catalyst solutions across the whole flowsheet to lower the pressure drop and/or lower the energy requirement.

Purification

Johnson Matthey has three offerings in addition to the typical HDS over ZnO used in many plants. The first two solutions offer a route to lower the pressure drop while the third provides a means to lower the energy demand of the system:

- KATALCO$_{JM}$ 33-1 is a 3-in-1 absorbent combining; HDS, sulphur capture and ultra-purification for feedstock purification.
- KATALCO$_{JM}$ 32-6 is a high density, promoted ZnO to increase sulphur removal capacity. Its promotion system makes it possible to deploy this solution at all sections of the purification where it can convert species such as COS and DMS to H_2S.
- KATALCO$_{JM}$ 61-2 and PURASPEC$_{JM}$™ 2020 is an HDS/ZnO system that is active even at lower temperatures, enabling energy savings.

Johnson Matthey's 3-in-1 solution, KATALCO$_{JM}$ 33-1, is based on a dual-promoted ZnO system. As the whole bed contains a catalytic HDS function so the risks of recombination chemistry, the recombination of H_2S to form organic sulphurs (most commonly COS), is reduced. Further advantage is gained where the sulphur levels are regularly at a very low level, in such cases an HDS material requires the purposeful addition of sulphur to the system so the catalyst remains in an active sulphided state. The 3-in-1 solution retains a sulphur distribution over the catalytic active components, making it active even in conditions where the sulphur levels are low and variable. The pressure drop saving is gained as this material can be used in place of the HDS material and so remove the pressure drop and cost of the HDS material altogether.

Johnson Matthey's high density promoted ZnO, KATALCO$_{JM}$ 32-6, allows more capacity to be gained per unit volume of absorbent. This is typically used to increase campaign length. However, it is possible to lower the pressure drop of a ZnO a system by loading less material, where a decrease in pressure drop is more valuable than an increase in campaign length. The pressure drop can be decreased by about 20-30% using this material for the same sulphur capacity. The additional benefit of this material is its increased reactivity to convert light sulphur species to H_2S and simultaneously remove them by trapping them as ZnS.

Johnson Matthey's high activity HDS catalyst, KATALCO$_{JM}$ 61-2, allows the amount of pre heat, typically gained from a coil in the convection section, to be reduced. Although most HDS materials operate at 300° to 400°C, KATALCO$_{JM}$ 61-2 allows lower temperature operation, from 250°C. Johnson Matthey has a complementary range of H_2S absorbents, including PURASPEC$_{JM}$ 2020, which operates efficiently at the same temperature.

Fig 6: **Pressure drop profiles over catalyst beds for two ammonia flowsheets**

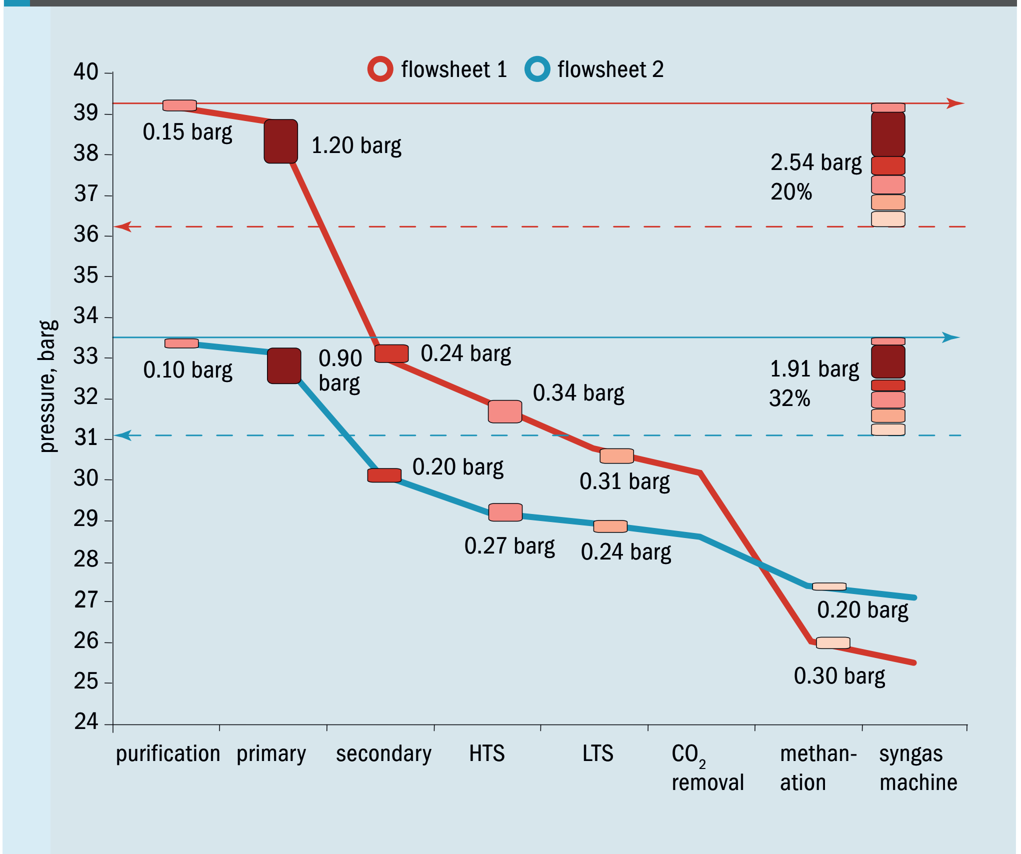
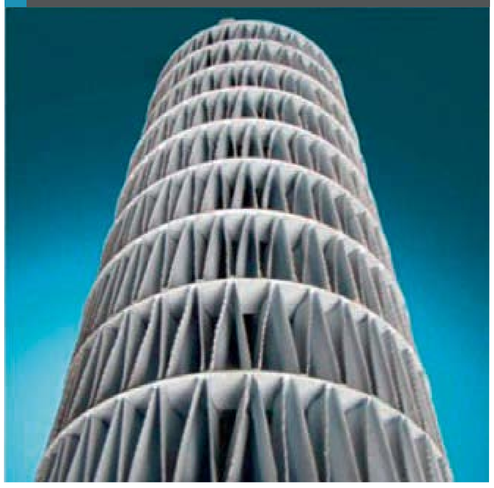


Fig 7: **CATACEL$_{JM}$ SSR stack**



Primary reforming

Over the years, Johnson Matthey has led the way in lowering pressure drop. The high activity QUADRALOBE$_{JM}$ range of catalysts that Johnson Matthey offers provide the widest range of sizes. The latest addition to the range is the XQ size which further lowers the pressure drop and provides an optimised activity.

Johnson Matthey's CATACEL$_{JM}$ SSR™ (Fig. 7) provides the next development by way of a catalyst supported on an engineered foil instead of on traditional ceramic-based pellets. The foil support is shaped into fans upon which catalytic material is applied. The fans are then stacked, separated by thin metal washers and reinforced by the central support. The whole assembly is then placed inside the tube.

CATACEL$_{JM}$ SSR provides the following advantages:

- lower pressure drop;
- high heat transfer;
- high activity.

The flow pattern through the tube is extremely well defined by virtue of the engineered support. The design can be tailored to maximise the benefit in a customer plant.

Using Johnson Matthey's simulation tools the flow pattern and performance of the system can be reliably predicted,

Fig 8: CFD assessment of the flow pattern as part of a CATACEL$_{JM}$ SSR design

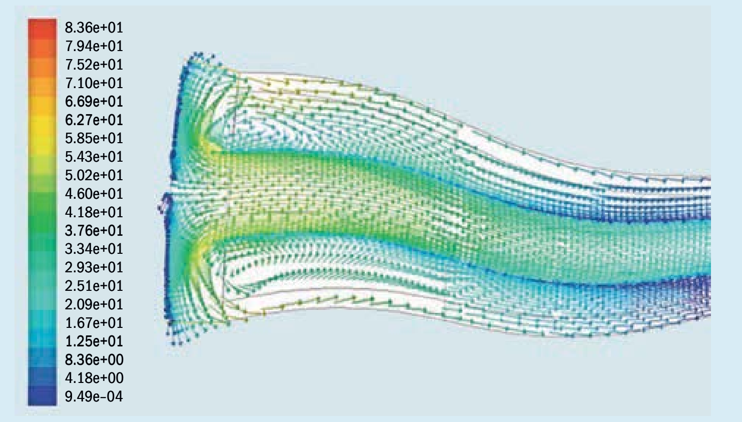
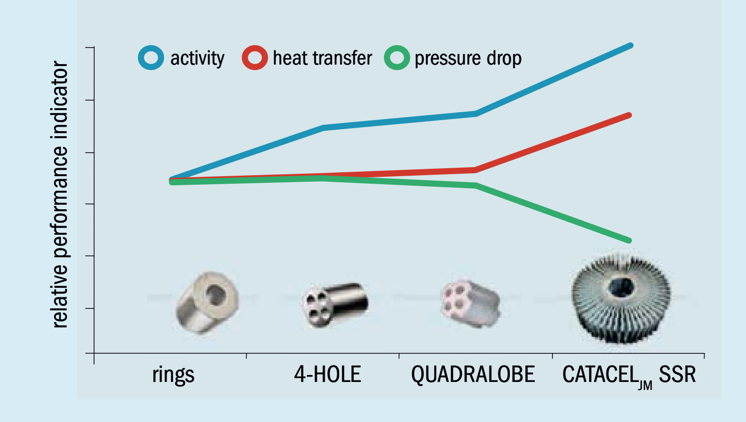


Fig 9: CATACEL$_{JM}$ SSR is a step change in primary reforming catalyst technology



as shown in Fig. 8. Johnson Matthey's proprietary software, PRIMARY, can be used to project the performance of the technology.

Fig. 9 shows this performance relative to the earlier technologies, illustrating the benefits this development brings to the operator.

Each shape development has broken the rules that previously governed the relationship between heat transfer and pressure drop. CATACEL$_{JM}$ SSR represents the single biggest step forward in this respect. It is now possible to further lower pressure drop and increase activity, providing step changes in the performance of our customer's plants.

Secondary reforming

Johnson Matthey provides a full range of catalyst sizes into this application. The QUADRALOBE shape provides a material with a high GSA / unit volume, whilst not relying upon a large number of small holes in the material to achieve this.

Shape optimisation ensures that the QUADRALOBE catalyst avoids small holes that are more prone to becoming blocked. This is important as alumina vaporisation in the hotter regions of the bed can result in deposition of alumina in the cooler regions and so lead to a build-up of the catalyst bed pressure drop. This often forms a distinct layer in the catalyst bed, and the normal solution to this is to skim and replace the affected catalyst where the fouling is occurring.

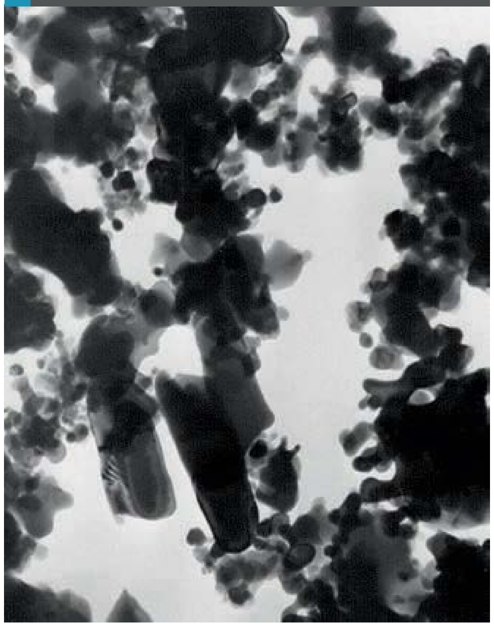
Often, the condensed alumina crystals will exhibit a pink or red colour and the alumina is then in the form of synthetic rubies, as shown in Fig. 10. Rubies are naturally occurring corundum (alumina) with trace quantities of chromium, which cause the pink colour.

Johnson Matthey experimented with a number of different catalytic metals and ceramic supports in an attempt to eliminate the problems of catalyst vaporisation. This resulted in the development of KATALCO$_{JM}$ 89-6, a catalyst designed for the top of secondary reformers and autothermal reformers (ATRs). The catalyst utilises a refractory metal as the active component on a stabilised high temperature ceramic support. The equilibrium vapour pressure of the ceramic used is several orders of magnitude lower than alumina, resulting in substantially lower vaporisation rates. Side by side trials of alumina-based catalyst and KATALCO$_{JM}$ 89-6 have confirmed these lower vaporisation rates and an elimination of this problem as a source of pressure drop increase.

As part of its range, Johnson Matthey provides active guard layer catalysts. These are larger sized materials, 'extra giant' (XQ) and 'Elephant' (EQ) sized grades are used where the design allows for this catalyst option, so that even the very top section of the bed is carrying out reforming, generating hydrogen and removing heat from the system, and not creating extra pressure drop.

Fig 10: Crystalline deposit on catalyst pellets in secondary reformer

Fig 11: SEM showing the micro-structure in KATALCO$_{JM}$ 71-Series



Water gas shift

The typical configuration is to use two large beds, a high temperature shift (HTS) and a low temperature shift (LTS) bed, to perform the water gas shift reaction. These unit operations are vital to the flowsheet as they convert CO, produced by the reforming reaction, to hydrogen and CO_2. The lower the CO level exit the shift beds, the greater the hydrogen yield and so the better the efficiency of the flow sheet. There is almost always an incentive to reduce HTS and LTS pressure drop by:

- optimal catalyst design;
- utilising lower pressure drop support media / support grids;
- reactor design.

Fig 12: **The pore size distribution in KATALCO$_{JM}$ 71-Series**

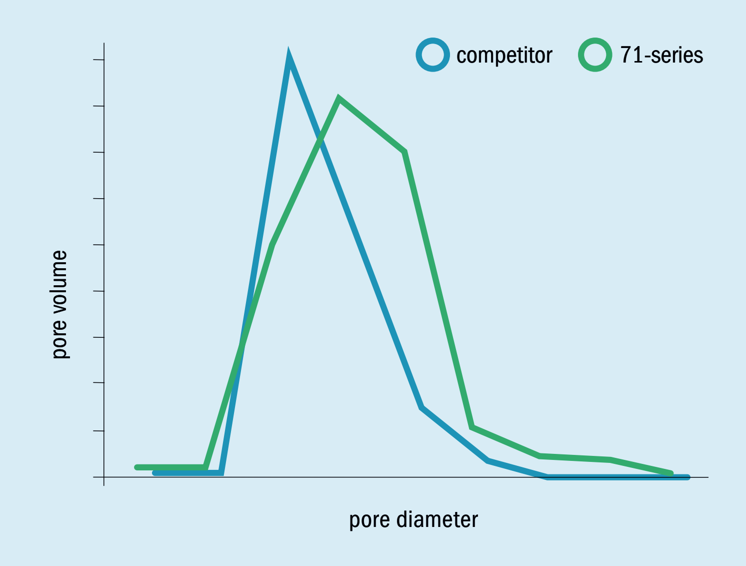
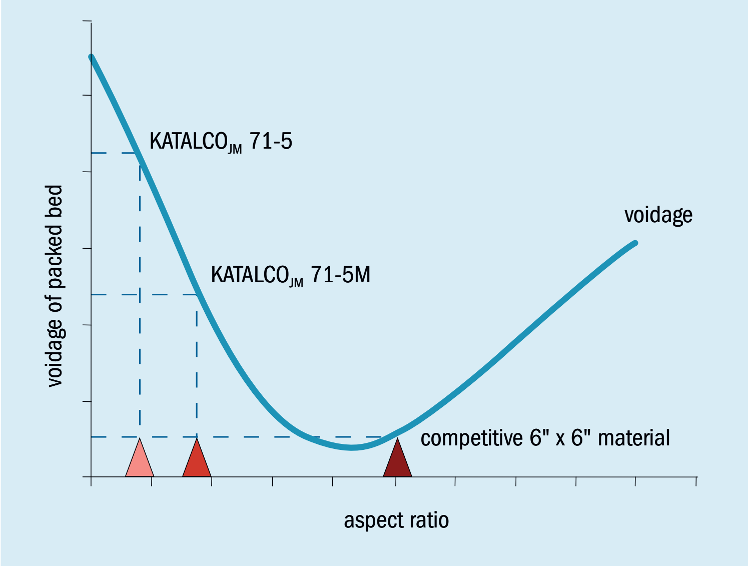


Fig 13: **Voidage of different HTS pellet geometries**



HTS

Unlike the reforming catalysts which are supported catalyst, the HTS material is a precipitated catalyst. This is because the operating temperature has fallen from a temperature of 700-1,000°C to <500°C, which means a precipitated catalyst can be operated successfully, as the structure of the material will remain intact at these temperatures.

The HTS catalyst deactivates through a sintering mechanism, so avoiding operations in excess of the design temperature for the HTS catalyst will help prolong the life of the material. However, as Fig. 6 shows, the rate of reaction will be reduced as the temperature is lowered and so it would require a larger volume of catalyst to gain the same effect. In turn this will increase the pressure drop and so multiple trade-offs need to be considered to provide the optimal solution.

KATALCO$_{JM}$ 71-Series is manufactured from a unique nitrate route using an active structural promoter, which opens up the pore structure. The pellet geometry has also been optimised to minimise the pressure drop. KATALCO$_{JM}$ 71-Series provides a network with larger pores to increases the path ways that enable effective diffusion at an atomic scale. Fig. 11 shows a scanning electron microscope (SEM) image of the modified atomic structure and Fig. 12 shows the impact this has in terms of the increase in the size and number of pores which allows reactants to access the internal active sites more rapidly.

Finally the pellet geometry maximises the voidage and so decreases the pressure drop through a packed bed of the KATALCO$_{JM}$ 71-Series catalyst. The relationship between aspect ratio and voidage is plotted in Fig. 13. This shows the superior aspect ratio of the pellet geometry Johnson Matthey utilises, offering catalyst pellets that pack to a higher voidage and thus a lower pressure drop compared to other catalyst geometries available.

Fig 14: **KATALCO$_{JM}$ 71-5F**

Johnson Matthey has recently introduced KATALCO$_{JM}$ 71-5F to the market. This catalyst is based on the same precipitation route and chemistry that is well proven in the market, but the shape has been optimised resulting in an enhanced 5-lobe shape that offers increased performance with lower pressure drop, increased strength and increased voidage (Fig. 14).

LTS

The LTS catalyst life is normally limited by deactivation due to the poisons, sulphur and chloride. These can also enter through the air intake to the secondary making the LTS susceptible to attack, even when the upstream purification system is working effectively.

For the LTS material to provide a long stable performance over its life time, it needs to manage the poisons that are presented to it. Johnson Matthey offers self-guarding materials, KATALCO$_{JM}$ 83-Series, which are able to trap sulphur and chloride at the top of the bed. This chemistry is achieved by providing a location that can stably harbour the poisons without causing structural weakness. In each case this stable trapping mechanism is paired with a kinetically rapid capture mechanism, by virtue of the material manufacture. The results of this self-guarding mechanism are shown in Fig. 15.

The self-guarding feature of the catalyst, with no need for a guard layer, can be used to:

- reduce the installed volume and hence pressure drop or;
- maximise the activity and life by charging the whole vessel with active LTS material.

In each of the plants shown in Fig. 15, the KATALCO$_{JM}$ catalyst gave significantly

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 53 54 55 56 57 58 59 60 61 62 63 64

Fig 15: **Achieved catalyst lives of KATALCO$_{JM}$ and competitor LTS product in operation in 20 different plants**

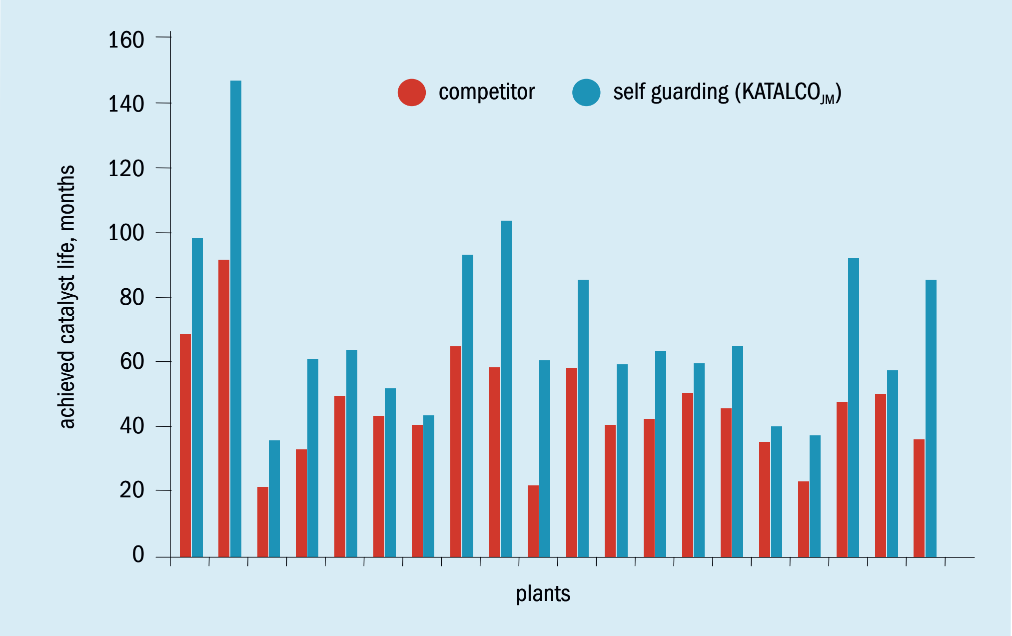
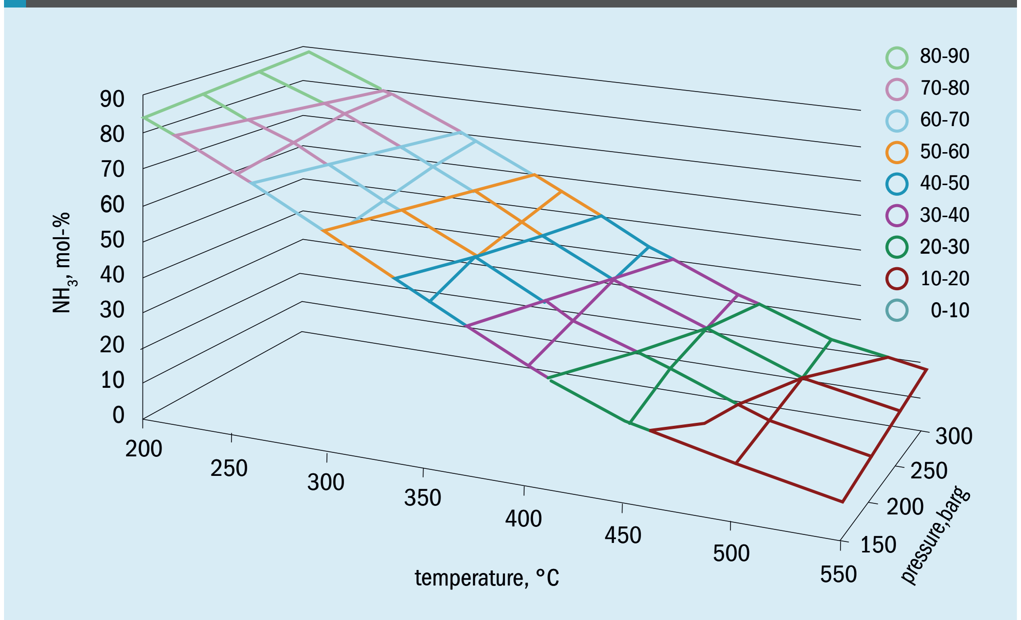


Fig 16: **Ammonia equilibrium position with varying temperature and pressure, from a feed of H_2:N_2 with a gas ratio of 3:1 (mol:mol)**



longer operating lives, giving customers more economic performance by operating at equilibrium for longer than the competitive products.

Further efficiency can be gained by installing a low methanol LTS catalyst, KATALCO$_{JM}$ 83-3X. This is a promoted material that alters the active sites so the catalysts ability to produce methanol is vastly reduced.

Methanation

This duty removes the last traces of carbon oxides from the system by converting them to methane. This is a requirement because carbon oxides deactivate the downstream ammonia synthesis catalyst.

Johnson Matthey offers a range of catalysts that can be selected to suit specific plant requirements, such as low temperature operation (see case study 2 below) and/or low pressure drop.

KATALCO$_{JM}$ 11-4 offers the ability to reduce the inlet temperature of the methanator. This saves energy and can be an efficiency benefit on some plants. In itself, reducing the temperature of operation also slightly reduces the pressure drop. To achieve this, the low-temperature kinetics of the catalyst (see Fig. 5) are enhanced via an optimised nickel loading that retains its surface area in service. It furthermore requires a pellet shape that maximises the packing efficiency in the bed, as there is a requirement to pack as much activate surface into the available bed volume. This product has a long track record of excellent operation having been developed for the ICI Leading Concept Ammonia Process (LCA), in which the inlet temperature was lower by virtue of the LCA flow sheet design.

Johnson Matthey's latest developments in methanation, provide lower pressure drop solutions. This is achieved by increasing the bed voidage through shape optimisation.

Ammonia synthesis

Since the reaction is not equimolar, pressure has a notable effect on the equilibrium position. The advantages of higher pressure are shown in Fig. 16. There is also an equilibrium gain from low temperature, however kinetics mean that commercial loops operate at higher temperature.

For a wide range of pressures KATALCO$_{JM}$ ammonia synthesis catalysts offer robust and reliable performance. These are a multi-promoted magnetite catalyst, which can be provided in an oxide or pre-reduced and stabilised form.

The pre-reduced and stabilised material offers the benefits of:

- faster reduction / commissioning of the material;
- lower reduction temperature, overcoming potential operational limits on start up;
- produces less water (ammonia solution) to be managed / disposed of.

These all aid the efficiency of the process.

In ammonia synthesis, one of the most notable developments was the introduction of cobalt to further improve magnetite ammonia synthesis. The addition of cobalt in this catalyst brings two major effects compared to conventional magnetite catalysts; easier reduction and higher activity. Johnson Matthey's ammonia synthesis catalyst regularly achieves lives of >20 years.

Case study 1: Pressure drop savings

By applying these catalyst solutions it possible to save 0.7-1.0 barg pressure drop over the front section of the flowsheet. This assessment has been carried for the two flowsheets detailed in Fig. 6. Table 4 looks at the typical split of this saving over the different duties.

Assuming a gas price of \$2 /MMBtu, gas consumption of 36 MMBtu/t NH_3 and other costs of \$26/t NH_3, the cost of producing the NH_3 is \$98/t NH_3.

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 53 54 55 56 57 58 59 60 61 62 63 64

Table 4: **Split of the pressure drop savings over the duties in the front section of the flowsheet**

Duty	Change in catalyst technology	Pressure drop saving, %	Initial pressure drop		Optimised pressure drop	
			Flowsheet 1, barg	Flowsheet 2, barg	Flowsheet 1, barg	Flowsheet 2, barg
Purification	HDS/ZnO exchanged for 3 in 1 solution	25	0.15	0.1	0.11	0.08
Primary	Pelleted material exchanged for foil supported solution	60	1.2	0.9	0.48	0.36
Secondary	Use of shape optimised material vs competitive material	25	0.24	0.2	0.18	0.15
HTS	Use of shape optimised material vs competitive material	30	0.34	0.27	0.24	0.19
LTS	Use of shape optimised material vs competitive material	5	0.31	0.24	0.29	0.23
Methanation	Use of shape optimised material vs competitive material	15	0.3	0.2	0.26	0.17
Total pressure drop over the installed catalyst volume			**2.54**	**1.91**	**1.56**	**1.17**
Total pressure drop saving over the installed catalyst volume					**0.98**	**0.74**
Total saving, %					**39**	**39**

With a selling price of \$400/t NH_3 the margin is \$302/t NH_3. If decreasing the pressure drop by 1.75 psi enables the plant to achieve a 0.5% increase in output, this means the saving is worth: \$490,000/year for flowsheet 1, which has a nameplate capacity of 1,600 t/d, and \$450,000/year for flowsheet 2, which has a nameplate capacity of 1,900 t/d.

Case study 2: Lower temperature operation savings

After a revamp to convert a CO_2 removal system to use aMDEA to lower slip exit the absorber, a consequence was that the methanator feed-effluent exchanger (E307), could not raise the methanator inlet temperature to the normal running condition of 290°C. A HP steam heater was used consuming 4-5 t/h of 100 bar steam to raise the methanation inlet temperature as shown in Fig. 17.

By installing a $KATALCO_{JM}$ 11-4, a catalyst with the highest intrinsic kinetic activity this has allowed operation with an inlet temperature 65°C lower, at 220°C. As a result, the HP steam consumption was reduced by 2-3 t/h, (see Fig. 18). This corresponded to an improvement in energy efficiency of 0.15GJ/t NH_3 (0.142 MMBtu/t NH_3). The value of these changes is worth €250,000-500,000/year for a 1,000-2,000 t/d flowsheet. This was based on a gas price of \$6/1MMBtu and an exchange rate of 0.9 Euro:USD.

Fig 17: **Classic higher temperature methanation**

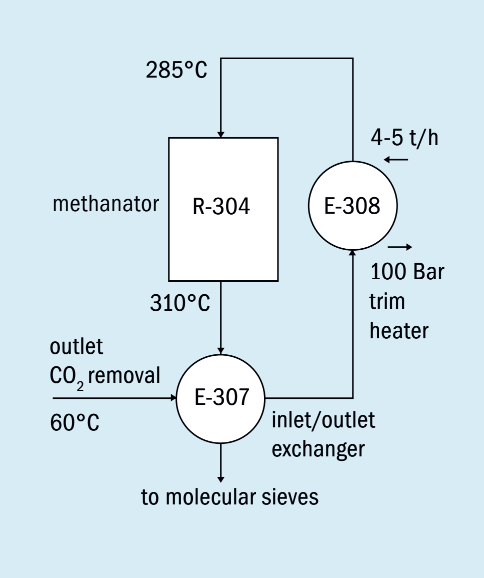
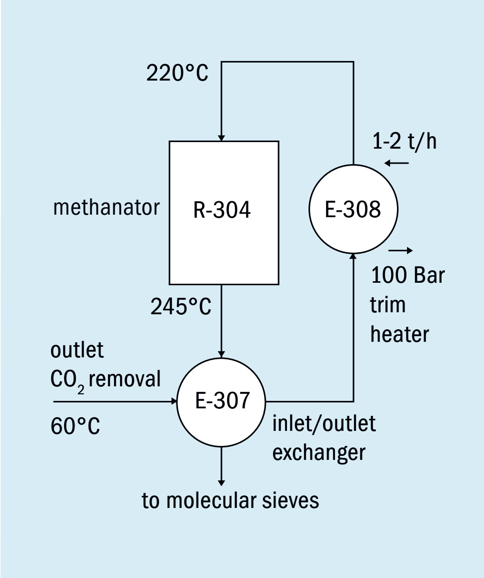


Fig 18: **Lower temperature methanation with $KATALCO_{JM}$ 11-4**



$KATALCO_{JM}$ 11-4 has provided very stable operating performance at these challenging conditions with the achieved life now into the tenth year, with carbon oxide slip below 3 ppm.

Conclusions

What is so attractive about these savings is they can be taken in a step wise fashion to align with existing catalyst change-out needs. The value of increased efficiency when exchanging an old catalyst with a new optimised one can normally pay for the optimised catalyst charge within 1-2 years of operation.

References

1. Broeck SVD and Fowles M: "Low temperature methanation: Operating experience something unexpected!". 2008 AIChE Ammonia Safety Symposium, San Antonio, Texas USA.
2. McKidd AW, Broadhurst PV and Macleod N: "Introducing $KATALCO_{JM}$ 33-1 a tri-functional purification solution for sulphur removal from synthesis gas plant feedstocks. Nitrogen + Syngas Conference, Bahrain (2010).
3. Whittenberger W and Farnell P: "Foil supported catalysts deliver high performance in steam reformers". Nitrogen + Syngas Conference, Istanbul (2015).

Advertisers' index

Advertiser	Page	Contact	Fax / Email
AIChE Annual Safety in Ammonia Plants Symposium 2017	17	Ms Rebecca Matos	1 646 495 1324
AUMUND Fordertechnik	35	Dr N Velten	velten@aumund.de
CRU's Nitrogen+Syngas Conference 2017	55	Ms Hayley Ward	Hayley.ward@crugroup.com
Casale	28/29	Ms Rosella Gazzaniga	41 91 960 7291
Clariant Produkte (Deutschland) GmbH	23	Ms Julie Reinherr	julie.reinherr@clariant.com
Eurotecnica Contractors and Engineers	5	Mr Stefano Sassi	s.sassi@eurotecnica.it
Eurotecnica Contractors and Engineers	OBC	Mr Stefano Sassi	s.sassi@eurotecnica.it
Haldor Topsoe	13	Mr Esben Rosenberg Sørensen	Esrs@topsoe.dk
Integer Research	45		www.integer-research.com
Johnson Matthey	IFC	Ms Gillian Standley	44 1642 522 542
Quest Integrity Group	15		sales@questintegrity.com
Sabin Metal Corporation	9	Mr Bradford Cook	bcook@sabinmetal.com
Schoeller-Bleckmann Nitec	39	Mr Herman Kernberger	43 2630 31919
Value Added Fertilizer Summit Asia 2017	43		conferences@integer-research.com

Next issue: March/April 2017

Distribution at: Nitrogen+Syngas 2017 Conference, London

- Sourcing gas in Europe
- The effect of carbon markets
- Strategies for hydrogen production
- First performance assessments of innovation urea technologies
- Personnel and equipment protection in ammonia plants
- Nitrogen+Syngas 2017 preview

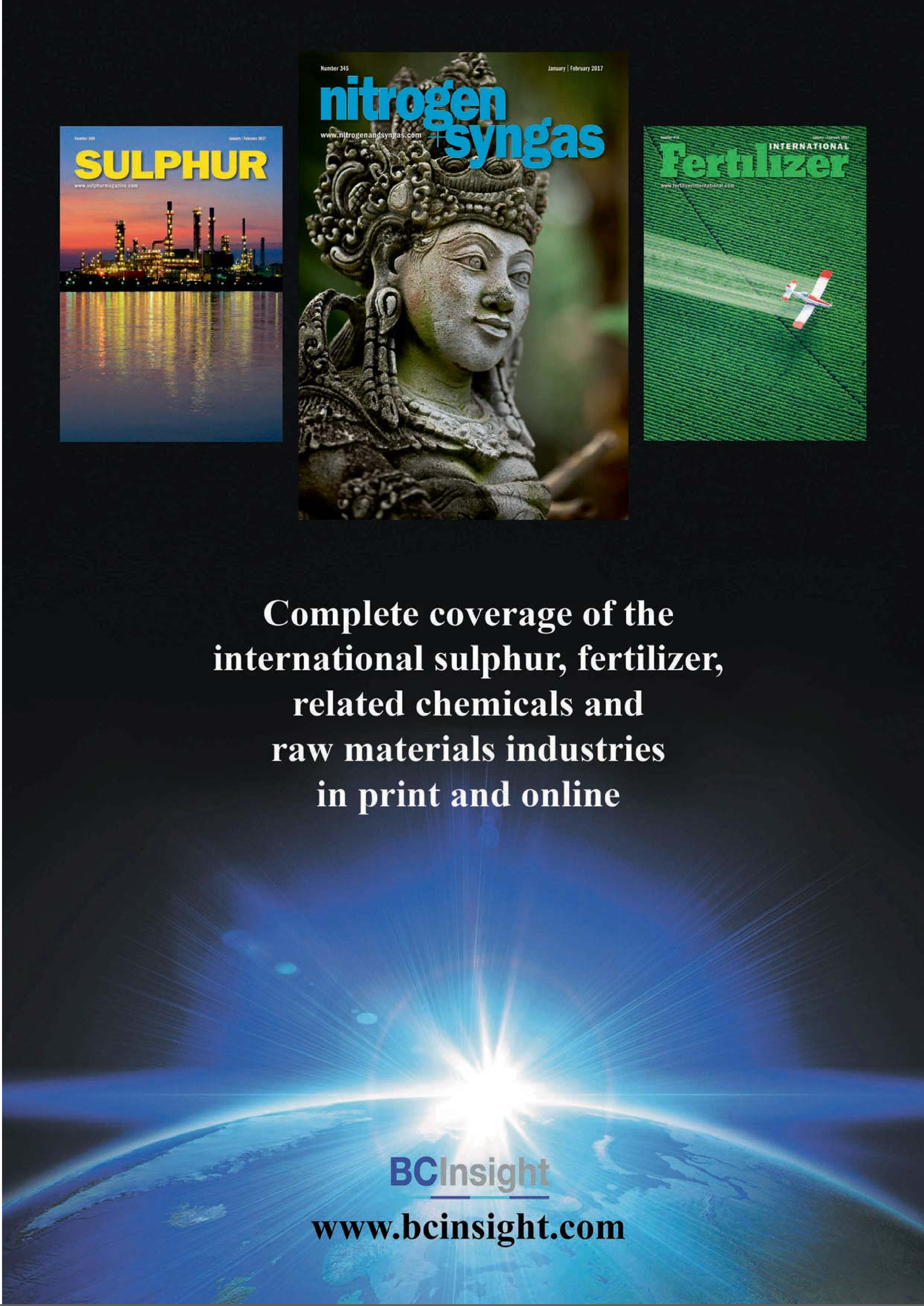
Full details of features can be found in the 2017 Media Prospectus, download a copy at www.bcinsight.com

Closing date for advertisement space booking is 10 February 2017
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
Contributors:
LAURA CROSS
laura.cross@integer-research.com
MIKE NASH
mike.nash@ihs.com
Publishing Director: TINA FIRMAN
tina.firman@bcinsight.com
Subscription rates:
GBP 425; USD 850; EUR 655
Subscription claims:
Claims for non receipt of issues must be made within 3 months of the issue publication date.
Subscriptions Manager / enquiries:
MARIETTA BESCHORNER
Tel: +44 (0)20 7793 2569
Fax: +44 (0)20 7793 2577
marietta.beschorner@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 *Nitrogen+Syngas* and *Nitrogen & Methanol* from 1996 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: 1750-6891
Design and production:
JOHN CREEK, DANI HART
Mixed Sources
Product group from well-managed forests and other controlled sources
www.fsc.org Cert no. SA-COC-001904
© 1996 Forest Stewardship Council
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


SULPHUR
www.sulphurmagazine.com
Number 345
January | February 2017
nitrogen
+syngas
www.nitrogenandsyngas.com
INTERNATIONAL
Fertilizer
Complete coverage of the international sulphur, fertilizer, related chemicals and raw materials industries in print and online
BCInsight
www.bcinsight.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 53 54 55 56 57 58 59 60 61 62 63 64