Number 360

July | August 2019

nitrogen+syngas

60 YEARS ANNIVERSARY 1959-2019

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Ammonia leaks

Preventing production, handling and transport incidents.

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Safurex® Star*

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BCInsight

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REGULARS

India's big decision

In late May, India re-elected prime minister Narendra Modi and his nationalist Bharatiya Janata Party (BJP) by another wide margin, giving the man who has changed the face of Indian politics another five year term and a strong mandate for the economic reforms that he has put in train. This may encourage him to be bolder than he was in his first term, which although it saw economic growth, large-scale infrastructure investment and an overhaul of the tax system, did not achieve the deeper, more politically painful overhauls of labour markets and the agriculture sector that his advisors have been advocating.

There are signs that this may already be happening, with recent reports in the Indian press suggesting that the new government is now considering moving urea under the umbrella of the nutrient-based subsidy (NBS) scheme which most other major fertilizers are part of. NBS annually fixes the subsidy rates for each tonne of nutrient present in a fertilizer; nitrogen, phosphorus, potassium and sulphur. Urea, however, has always remained outside the NBS scheme because it was seen as too politically sensitive, and is sold at a statutory uniform price, currently fixed at 5,360 rupees/tonne ($77.63), far below the international market price of around $250/tonne. Urea is by far the most commonly used nitrogen fertilizer in India, and many of the smaller, poorer farmers who are a key electoral demographic rely upon it being widely and cheaply available. While moving urea under the NBS would reduce the overall subsidy level paid by government, it would also make urea more expensive for farmers to buy. This may not be a bad thing – India over-applies nitrogen nutrient compared to P and K precisely because urea is so cheap – however, it would also be politically difficult.

"The government is unlikely to completely decontrol urea prices.

For this reason, the government is unlikely to completely decontrol urea prices in the way that it has the prices of most other fertilizers. There is a suggestion that it might be allowed to move within a band defined by a minimum and maximum price depending upon the external market situation, reviewed quarterly. The government can also control urea distribution through Fertilizer Control Orders and the Essential Commodities Act, which allows states to mandate stockpiling limits beyond which holders of stockpiles of commodities deemed to be essential must sell their holdings onto the market.

A rise in the domestic price of urea would certainly ease the government's fertilizer subsidy bill, which reached a record 1 trillion rupees last year ($14.5 billion), and which is set to increase further as new urea plants, the construction of which has been encouraged by the Modi government to reduce India's dependence on overseas imports, start to come on-stream over the next few years. Domestic producers face far higher prices for natural gas compared to competitors in the Arabian Gulf or Russia, as India is short of natural gas and imports much of its requirement from overseas as liquefied natural gas (LNG). LNG prices are at historic lows at the moment because of oversupply in the market, but even delivered prices of $5.60/MMBtu compare unfavourably with the $1.00-2.00/MMBtu that producers in Russia or the Gulf can pay, and a lack of new investment in LNG supply means that prices are likely to spike back up over the next few years.

At the moment there is no hint to how the government is thinking of changing urea subsidies. The fertilizer ministry only commented that; "the modalities are under discussion." Furthermore, prior to the election, the BJP promised that no change would be made to the current system during the current financial year, so the earliest any change could be made would be April 2020. Still, it looks as though change may finally be coming to India's urea subsidies. ■

Richard Hands, Editor

Price trends

MARKET INSIGHT

Alistair Wallace, Senior Manager, Consulting, Argus Media, assesses price trends and the market outlook for nitrogen.

NITROGEN

The slow price depreciation that has been a constant theme in the ammonia market this year shows no sign of abating, but there are some signs of improvement in both western and eastern markets and opinions are beginning to diverge about sentiment ahead of the third quarter. The tone for June was set by another $17/t drop in the Tampa contract price to $220/t c.fr – a 21-month low – setting a new f.o.b. price of around $180/t. The Americas continues to represent the weakest price point in the market, with good availability in Trinidad and the US Gulf. East of Suez markets are faring better, and Indonesian producers are managing to sell product at above $250/t f.o.b., representing the firmest region in the market for the second quarter.

With the market split, many are monitoring Yuzhnyy closely for June and July availability for a sign of which way the market will go next. Yuzhnyy is traditionally the balancing point in the market, but TogliattiAzot – the largest Russian export through Yuzhnyy – has given no signals that it is about to reduce production.

The picture is mixed in the Middle East, where prices slumped close to $200/t f.o.b. in May and are testing $190/t f.o.b. in early June. More tonnage is available from Oman and Iran currently, with the latter having begun to send regular cargoes to China, a trend that could change the supply outlook in east Asia if it continues into the second half of the year. Elsewhere, supply disruption at Fertial in Algeria is having a minor knock-on effect in the region.

The east of Suez markets overall have been very quiet in terms of spot trade in the second quarter, but buyers have watched freight costs escalate in the first half of June in the wake of the tanker incidents in the Middle East Gulf.

The urea market has firmed, unusually, during the second quarter and will continue to do so into the second half of the year. Producers in most regions have begun June in a comfortable position, either fully committed or with only limited tonnages to sell for the second half of the month. There is little demand left to be covered in June but some spot requirements remain for Europe and Australia.

Prices for urea have moved up to $285/t f.o.b. in the Middle East and Egypt, while Baltic prills have sold in the high-$250s/t f.o.b.. This is approximately $30/t higher than a year ago. Average prices for the year to date are running $9/t higher in the Middle East, $12/t higher in Egypt and $19/t higher in the Baltic. Traders are already positioning for July, booking cargoes in North Africa above $280/t f.o.b.. We expect prices to remain strong through Q3 ahead of the peak demand period in October-November. There is a risk of the market overheating in Q3 and seeing a consequent price correction if Chinese exports rise rapidly.

Some Chinese urea has traded for July shipment at prices in the mid-$270s/t f.o.b., but prices do not need to fall further to be competitive. Chinese prilled urea has yet to feature for export and a two-week delay to the summer season is likely to mean that exports only start in significant volumes for August.

Indian urea stocks fell to about 1.1 million t at the end of May, compared to 1.7 million t at the end of May 2018. Production is also falling short of planned levels in India due to plant outages. Output in April-May was about 400,000 t lower than in the same months of 2018. Sales have not fallen.

Brazilian imports of urea are forecast to rise to more than 500,000 t/month in Q3 and will account for much of the Algerian, Nigerian and Iranian export availability. Iran appears to be shipping about 200,000 t/month of urea to Brazil but, despite this, prices in Brazil have firmed by about $10/t over the past month. Netbacks from Brazil are set to lag those from India for Middle East and Egyptian producers.

The lack of forward sales by traders means that the European market is totally uncovered for the 2019-20 season. The main European markets (excluding Turkey) import more than 500,000 t of granular urea in Q3 and more than one million t in Q4 each year.

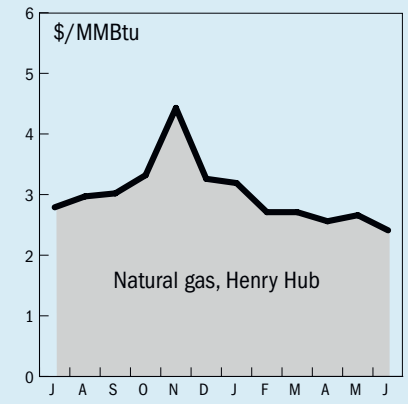
Table 1: **Price indications**

Cash equivalent	**mid-Apr**	**mid-Feb**	**mid-Dec**	**mid-Oct**
Ammonia ($/t)				
f.o.b. Black Sea	242-250	260-280	270-290	335-360
f.o.b. Caribbean	223-228	240	280-290	305-316
f.o.b. Arab Gulf	245-255	270-285	280-305	340-365
c.fr N.W. Europe	275-290	310-325	330-355	380-387
Urea ($/t)				
f.o.b. bulk Black Sea	224-230	230-240	270-280	280-300
f.o.b. bulk Arab Gulf*	247-272	233-255	280-290	320-340
f.o.b. NOLA barge (metric tonnes)	265	245	261	316
f.o.b. bagged China	300	260-285	275-290	320-338
DAP ($/t)				
f.o.b. bulk US Gulf	353-369	390	425	458-461
UAN (€/tonne)				
f.o.t. ex-tank Rouen, 30%N	235	238	268-274	253

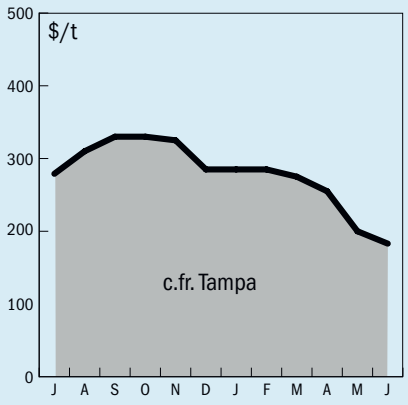
Notes: n.a. price not available at time of going to press.
*n.m. no market * high-end granular*

END OF MONTH SPOT PRICES

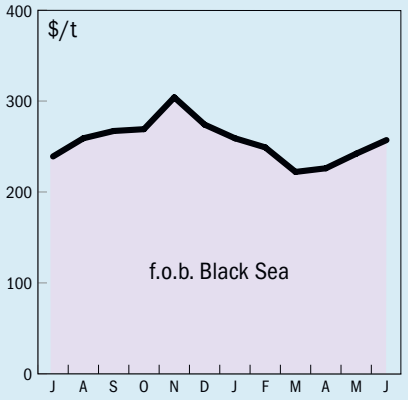
natural gas



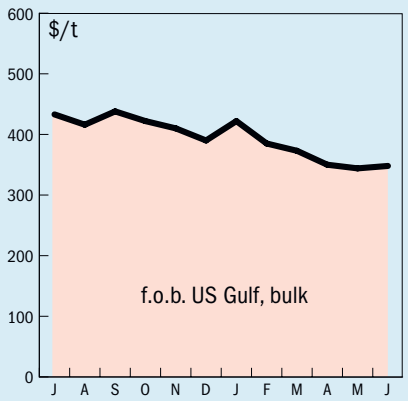
ammonia



urea



diammonium phosphate



MARKET INSIGHT

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

METHANOL

Spot methanol prices were flat in Asia and fell in Europe and the US in May due to stable supply in most regions and slightly softer demand. Official posted reference prices for June were $1.26/gal for Methanex (down 4 cents from May) and $1.17/gal for Southern Chemical, down 9 cents. These are equivalent to $419/t and $389/t, respectively. IHS Markit Chemical's contract net transaction price for June is officially posted at $1.219/gal (nominal $405/t), down $21/t from May. In the Americas, demand into most products was flat in May. Operations resumed at the ITC facility in early May, allowing the movement of raw materials and finished products in and out of the greater Houston Ship Channel. North American units operated at an overall rate of 90% on average during the month, and output was up in Trinidad and Venezuela, averaging 85% in both countries – the latter up considerably following outages related to electrical power interruptions. Methanex's Chilean unit is estimated to have run at a level of around 59% of nameplate capacity during May.

European spot prices (T2 f.o.b. Rotterdam) for May were down €5 from April at €266/t. Methanex's West European Contract Price was €360/t f.o.b. Rotterdam T2, a rollover from the previous quarter. Demand into chemical derivatives improved throughout May with acetic acid units restarting after planned maintenance. On the supply side, EMethanex in Egypt experienced an outage on 9 April and the plant remains offline. Methanex said that it expects limited production from the facility rom 2Q 2019 as repairs are made.

In India, port prices averaged $293/t in May, down $14/t from April due to higher import volumes from Iran during the month. Operating rates in Iran were improved at existing units and Kaveh is understood to have produced a cargo of methanol. The Marjan unit restarted in April following a two month maintenance outage. It is believed that the production from this unit so far has been sold to China into the MTO market.

Asian prices in May were flat to the previous month but in a wider range of $265-325/t c.fr; c.fr China prices were up $11.50/t on average in a range of $278-289/t, although Methanex's posted APCP for June is $350/t, down $20/t from.

Chinese capacity utilisation was up in May, averaging around 52% of nameplate capacity, or around 67% of effective capacity due to restarts at coal based units including Anhui Haoyuan. Coking gas-based methanol producers in North China ran at 44% utilisation while coal-based methanol plants in Northwest China ran at rates of 58%, up 4% from last month. The natural gas-based operating rate in China in May averaged 36%, down 2% from last month. The natural gas price for non-domestic usage declined by 10% starting on 1 May. Some natural gas-based producers, who are currently not running at full rate, were intending to increase their operating rates once the production cost reduced.

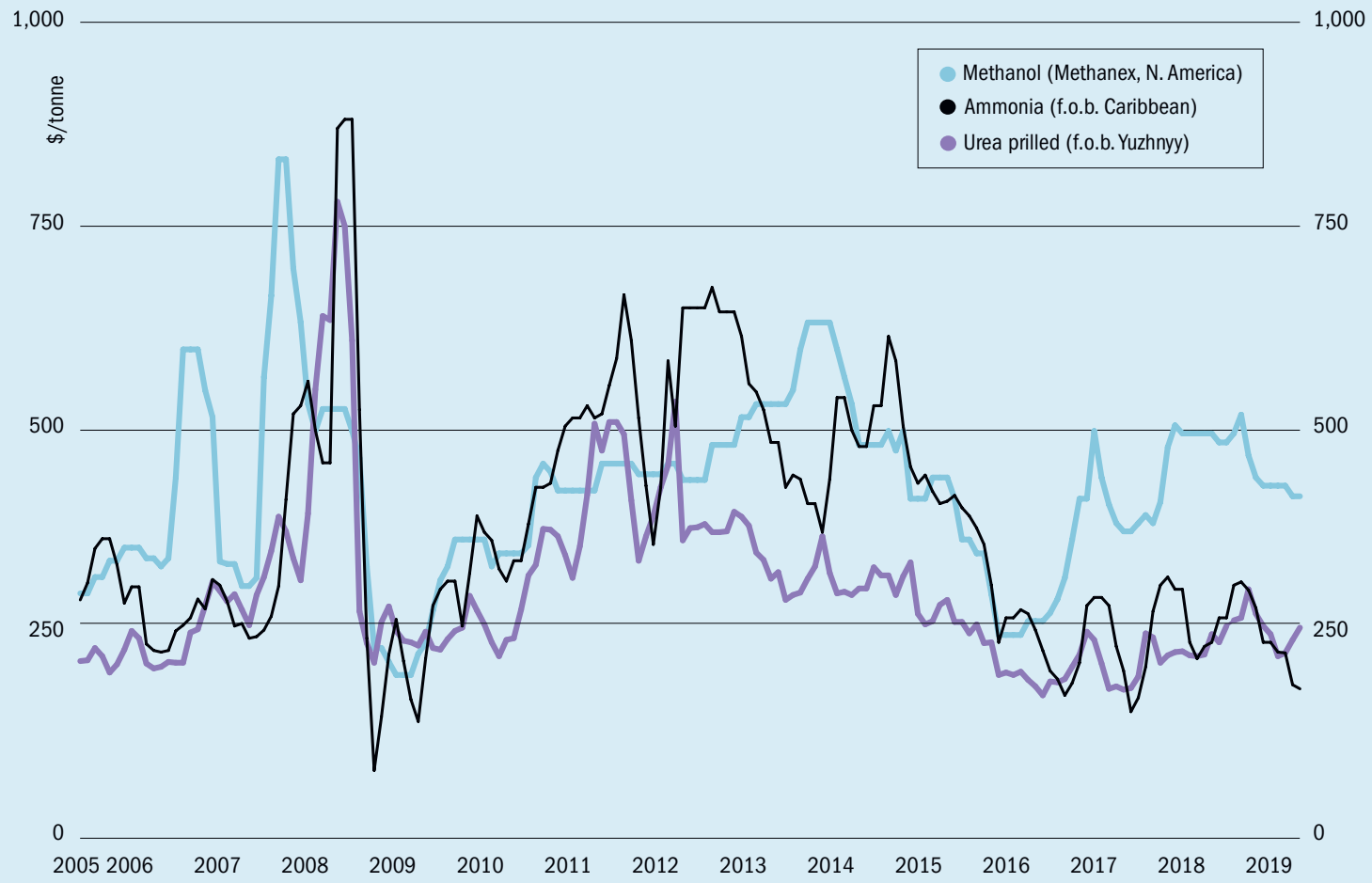
Demand into MTO in May was flat to the previous month, amid stable oil prices and economics. The average MTO operating rate was around 90%. Inner Mongolia Jiutai (1.8 million t/a methanol consumption) started up on 20 March with methanol feeding into the main equipment and began its second round of trial production during the last week of May. Nanjing Chengzhi II (also 1.8 million t/a methanol consumption) announced that it had achieved mechanical completion by the end of May and may begin commercial production within two months.

In Southeast Asia, regional supply improved. BMC had been offline since March for a turnaround but finally restarted in mid-May. Traditional downstream market supply-demand fundamentals were healthy. Acetic acid units were running to plan, although one producer reduced operating rates at the end of May for economic reasons. The MTBE and biodiesel markets were stable with producers. Petronas's second MTBE line's start-up time has been delayed to 4Q 2019.

In Korea, overall demand was bearish and inventory was high. The national acetic acid unit experienced reduced operating rates during May but was ramping up production towards the end of the month. It recently expanded its acetic acid capacity to 670,000 t/a. Methanol demand into energy applications such as MTBE was at a good level during May, with high operating rates. ■

Market outlook

Historical price trends $/tonne



Source: BCInsight

AMMONIA

- The outlook is not expected to change until at least the end of the month, with further price depreciations forecast throughout June. Many participants believe that the market will have to turn in early July as buyers finally accept the market is close to its bottom and start buying in earnest. Further seasonal demand may emerge in July, and the summer maintenance season could offer some support to pricing. East of Suez markets are forecast to be in deficit until the fourth quarter, but the weighty supply outlook west of Suez is unlikely to change in the near term.
- Chinese demand is likely to be a key factor in the months ahead. Buying has picked up in the past month and early estimates suggest that it imported around 100,000 t in May. If buying continues at this level it is likely to offer near-term support to pricing in east Asia, and keep the divergence in place between the east and west of Suez markets.

UREA

- India is expected to tender again during the second half of June for July shipment. MMTC is expected to seek the maximum possible quantity under its next tender, having bought just 1.1 million t so far in 2019-20. But as in the first two tenders, securing more than 500-700,000 t of urea may prove difficult without substantial Chinese involvement.
- Buyers currently face the choice of purchasing at current prices, which are seen as high, or waiting until later in Q3 and accepting whatever prices are prevailing at that time. Some may opt to purchase for July-August shipment in view of the likely rise in prices through to October-November.
- One consolation for European buyers is that they will face little competition from US buyers for spot urea cargoes in the second half of the year. Persistent wet weather means that corn planting in the US was at a record low as of 29 May and estimates of the area to be planted are being revised down.
- The fall in planted area of around 7.5 million acres may lead to a carryover of urea and other nitrogens into next year. Corn prices have jumped and bode well for demand in spring 2020 if they remain above $4/bushel.

METHANOL

- Bearish factors hang over methanol markets in Asia. Chief among these has been the ongoing US-China trade dispute, which is showing no signs of being resolved quickly.
- Iran has had some teething troubles with new methanol capacity at Marjan and Kaveh, but the two units have nevertheless added 4 million t/a of new methanol capacity in the Gulf.
- Two more Iranian plants, at Bushehr and Pars, are due to come on-stream by the end of 2019, adding another 3.3 million t/a of methanol capacity.
- However, Chinese MTO capacity is also increasing, with 3.6 million t/a of methanol consumption from new units forecast for 2019, and operating rates remain higher than average. ■

Nitrogen Industry News

RUSSIA

New ammonia plant comes on-stream

EuroChem has officially opened its new ammonia plant, EuroChem Northwest, at Kingisepp near St Petersburg in Russia, with a launch ceremony in St Petersburg attended by officials including Sergei Ivanov, Special Presidential Representative for Environmental Protection, Ecology and Transport; Denis Manturov, Minister of Industry and Trade; and Leningrad Region Governor Alexander Drozdenko. The plant, which cost $1 billion, has a capacity of 2,980 t/d (980,000 t/a), making it the largest single train ammonia facility in Europe, according to EuroChem. Engineering, procurement and construction was undertaken by Maire Tecnimont subsidiaries Tecnimont SpA and Tecnimont Russia OOO, with KBR licensing its *Purifier*™ ammonia process. Environmental features include a closed water recycling system to prevent effluent discharges into the nearby Luga River, which flows into the Baltic Sea in the Gulf of Finland. EuroChem says that it also continues to work closely with the John Nurminen Foundation on a major environmental project to prevent water runoff from any of its operations in Kingisepp. The plant was built on a brownfield site close to EuroChem's existing rail and shipping facilities, for easy export of ammonia to global markets. EuroChem will supply ammonia to its fertilizer production plants in Antwerp, Belgium, Lifosa in Lithuania, and Phosphorit, the Group's adjacent phosphate fertilizer facility in Kingisepp. About 25% of total output will be sold to third parties.

"The opening of EuroChem Northwest marks an important milestone in the company's growth story, and cements our position as a global leader in fertilizer production," said Petter Ostbo, chief executive of EuroChem. "By investing in the latest technologies, this landmark facility will help deliver world-class nutrients to our growing customer base, allowing farmers to get more out of their land."

Stamicarbon to design urea unit for ShchekinoAzot

Maire Tecnimont subsidiary Stamicarbon has been awarded a contract for a license and process design package together with proprietary equipment supply for a grassroots urea melt and granulation plant for ShchekinoAzot, to be built in Pervomayskiy, in Russia's Tula region. Stamicarbon will license and design a 2,000 t/d plant using its pool reactor and flash design, which simplifies synthesis loop operation, lowers investment costs and reduces steam consumption. The *Safurex*® high pressure stripper and pool reactor will be equipped with a radar level measurement system, while the granulation plant will use Stamicarbon's Optimised Granulation Design and *MicroMist*™ Venturi scrubber technology. This multi-stage gas scrubber for granulators is designed to remove urea particles and ammonia gas at extremely high efficiencies, and is capable of meeting stringent emission levels by capturing sub-micron dust and removing ammonia via the injection of an acidic solution, while minimising energy consumption by keeping pressure drop low.

NETHERLANDS

NH3 Event 2019

The 3rd European Power to Ammonia® to Conference took place 6-7 June 2019 at Rotterdam Zoo, in the Netherlands, bringing together industry and academics to discuss ammonia's role in the energy transition to a greener and more sustainable future. Attendance of the NH3 event has been growing year on year, rising to 165 participants this year, including 98 companies, universities, research and technology institutes, from 22 countries and five continents.

The theme of this year's event was building blocks for the complete chain for power-to-ammonia and ammonia-to-power. Well-known experts, developers and scientists representing the different building blocks of the chain presented their latest research results, current achievements and applications and shared their vision for business prospects in energy solutions.

The week of the conference coincided with an announcement that there would be a new carbon tax for energy producers in the Netherlands, a step towards making renewable energy become more competitive with energy from fossil fuels. Sustainable ammonia currently costs approximately twice as much to produce as conventional ammonia. However, the cost of renewable energy continues to fall, bringing the prospect of sustainable and affordable energy ever closer.

In the coming decades we face major challenges of how to transport and store energy from renewable sources. Ammonia is likely to be a part of the solution. Clean energy could double the demand for low carbon ammonia.

The keynote speech of the conference was given by Prof. Ad van Wikj of TU Delft who spoke about ammonia as a hydrogen carrier in the green hydrogen economy. So-called green hydrogen can be produced with effectively zero greenhouse gas emissions when it is produced by the electrolysis of water using electricity from renewable energy.

In some parts of the world renewable hydrogen is beginning to reach cost parity

with some fossil fuel equivalents. Australia, with its rich supply of renewable energy, including an abundant supply of solar and wind energy, is set to lead the way with high potential for export of renewable hydrogen. Existing export supply chains, including the supply of gas to regional neighbours in Japan and South Korea, provide a high potential market into which Australia can export hydrogen. Japan and South Korea have invested heavily in developing the role of hydrogen as part of their future economies, with the 2020 Tokyo Olympics set to use hydrogen to power the Olympic flame and power public transport.

Future potential applications for ammonia in the green hydrogen economy were highlighted including: direct use in diesel engines (ships, trucks) in the short term, direct use in gas turbines and furnaces in the short-to-medium term and direct use in fuel cells in the longer term. Ammonia, in particular, is regarded as one of the more attractive options for zero emission shipping due to its energy density and ease of handling.

A more detailed report on the topics discussed at the conference will be published in the September-October 2019 issue of *Nitrogen+Syngas*.

POLAND

Anwil to build new nitric acid and AN plants

Polish fertilizer company Anwil, a subsidiary of PKN Orlen, has awarded thyssenkrupp Industrial Solutions (TKIS) a contract for the construction of two new plants in Poland; a 1,265 t/d nitric acid unit, and an accompanying 1,200 t/d ammonium nitrate plant. Both will be sited at Wloclawek, 200 km northwest of, at Anwil's existing chemical and fertilizer complex. Anwil has an existing 360,000 t/a nitrates plant at the site, fed by a 500,000 t/a ammonia unit. As part of the contract, TKIS will implement its *EnviNOx* process to remove 3,200 t/a of N_2O and 1,000 t/a of other nitrogen oxides from the nitric acid plant's tail gases, converting them into nitrogen, oxygen and water, corresponding to a greenhouse gas equivalent reduction of about 1 million tonnes CO_2 per year.

The order includes the provision of technology licenses and the engineering, procurement and construction (EPC) of the new facilities. TKIS did not disclose the exact project cost, but put it in the "lower three-digit million euro" range. The project is a substantial part of a larger investment program being implemented by Orlen to expand its fertilizer portfolio and open up new value chains in the petrochemical industry. By 2022, the company aims to increase its fertilizer production capacity in Wloclawek by 50% to 1.46 million t/a, to meet growing demand in Poland.

"More than ever, the chemical industry faces the challenge of growing profitably and at the same time protecting the climate. With the realisation of this new, low-emission plant in Poland, ANWIL and thyssenkrupp are making an important contribution," said Sami Pelkonen, CEO Chemical & Process Technologies at thyssenkrupp Industrial Solutions. "We look forward to our further cooperation and are proud to bring decades of plant engineering and process know-how into the project."

UNITED STATES

Methane emissions from ammonia plants higher than estimated

Emissions of methane from ammonia plants have been vastly underestimated, according to researchers from Cornell University and the Environmental Defence Fund. The research, published in *Elementa*, used a Google Street View car equipped with a high precision methane sensor and travelled up and down public roads near six ammonia plants in the mid-West of the US to try and quantify fugitive methane emissions downwind from the plants – defined as inadvertent losses of methane to the atmosphere, likely due to incomplete chemical reactions during fertilizer production, incomplete fuel combustion or leaks. The researchers estimated that, on average, 0.34% of the natural gas used in the plants was emitted to the atmosphere. If this were scaled to the entire US ammonia industry, it would represent total annual methane emissions of 28,000 t/a – 100 times higher than the fertilizer industry's self-reported estimate of 200 t/a, and three times higher than the Environmental Protection Agency (EPA) estimate for all industrial processes in the United States.

John Albertson, co-author of the paper and professor of civil and environmental engineering at Cornell said: "It shows us that there's a huge gap between a priori estimates and real-world measurements. The presence of substantial emissions or leaks anywhere along the supply chain could make natural gas a more significant contributor to climate change than previously thought."

"Even though a small percentage is being leaked, the fact that methane is such a powerful greenhouse gas makes the small leaks very important," said Joseph Rudek, co-author and lead senior scientist at the Environmental Defence Fund. "In a 20-year timeframe, methane's global warming potential is 84 times that of carbon dioxide."

Cash secured for CCS project

Wabash Valley Resources says that it has secured an investment from the Oil and Gas Climate Initiative (OGCI) for what is expected to be the US' largest carbon capture and sequestration (CCS) project to date. The project began in 2016 when WVR acquired a world-scale gasification plant in Indiana, which it plans to convert into an anhydrous ammonia plant and CCS facility. The CCS plant is expected to capture 1.5-1.75 million t/a of CO_2 – depending on plant maintenance cycles – facilitating low carbon production of ammonia. It is expected to capture and sequester close to 100% of the ammonia plant's CO_2 via a Rectisol-based capture system, with attached compressor. The CO_2 will be sequestered around 2 km below the surface in a saline sandstone aquifer known as Mount Simon Sandstone. Conversion of the gasification plant and construction of the CCS plant is expected to begin in 2020 and completion is expected in 2022. It is expected to cost $600 million. WVR declined to disclose how much OGCI invested in the CCS project, which was chosen to receive funding from the US Department of Energy as part of the Carbon Storage Program. OGCI was founded in 2016 by oil majors including BP, Saudi Aramco and Shell, to fund the development of large-scale technologies to tackle climate change.

Pratima Rangarajan, CEO of OGCI Climate Investments, said: "CCUS [carbon capture, usage, and storage] will be a crucial part of the low carbon economy. Our investment in Wabash Valley Resources is a tangible demonstration of our commitment to CCUS as a tool to decarbonise the industrial sector. We look forward to working with Wabash Valley Resources team as they develop this project and demonstrate that CCUS is available today as a tool to combat climate change."

UNITED ARAB EMIRATES

Adnoc, OCI joint venture to create major regional player

The Abu Dhabi National Oil Company (Adnoc) has agreed to form a fertiliser joint venture with Dutch-based OCI. The move combines Adnoc Fertilizers with OCI's regional nitrogen plants in Egypt and Algeria to produce one of the largest exporters of urea, with combined annual sales of $1.74 billion. Adnoc will hold a 42% stake in the new joint venture and OCI, is owned by Egyptian billionaire Nassef Sawiris, the remaining 58%. The company's assets include 5 million t/a of urea capacity as well as 1.5 million t/a of merchant ammonia sales, most of this destined for export. OCI owns a plant in Egypt with 1.65 million t/a of urea capacity as well as a 60% stake in an Egyptian ammonia plant, as well as a trading arm in the United Arab Emirates. OCI's fertilizer venture in Algeria can produce about 1.6 million metric t/a of ammonia and 1.26 million t/a of urea.

The new company has also signed a new long-term gas supply agreement with Adnoc to provide feedstock for its UAE operations.

Dr Sultan Al Jaber, Adnoc Group chief executive and UAE Minister of State, who will also be chairman of the new company, said that the joint venture will enable Adnoc to "access new markets, benefitting both existing and new customers. Pooling our assets and capabilities is a value enhancing step for both companies, allowing us to leapfrog competitors to become the top nitrogen export platform globally," he said. The new company will have a centralised commercial team and storage and distribution infrastructure with access to key ports in the Mediterranean, Red Sea and Arabian Gulf.

IRAN

Pardis sets production record

Iran's National Petrochemical Company (NPC) says that its Pardis urea and ammonia plant achieved a new production and export record in the Iranian year ending March 20th 2019. NPC says that Pardis' ammonia output was 21% up on the previous year, and urea production up 32% over the same period. Domestic sales and exports grew by 48% year-on-year. Pardis is one of the largest producers of urea and ammonia in the Middle East, producing 3.23 million t/a of urea and 2.04 million t/a of ammonia last year.

SPAIN

Ammonia tank explosion kills one work and injures 14

One worker was killed on May 31st when a 20,000 litre ammonia storage tank exploded at the Sociedad Española de Carburos Metálicos facility at the town of La Pobla de Mafumet near the city of Tarragona in northeastern Spain. Another 14 were injured, including one who was airlifted to hospital in Barcelona in critical condition. Three of the injured were firefighters. The Catalan General Directorate of Civil Protection declared a state of emergency and the local population was advised not to approach the plant and keep all windows closed. The General Directorate said that prompt action by firefighters and emergency personnel had prevented a toxic cloud from forming over the locality, but local media reported that there was a strong smell of ammonia some distance from the plant. Carburos Metálicos is an industrial gas supplier and a subsidiary of US-based Air Products.

AZERBAIJAN

SOCAR to build new urea plant

Azerbaijan new agency Trend reports that at a May 31st meeting between Rovnag Abdullayev, president of Azerbaijan's SOCAR (State Oil Company Azerbaijan Republic), and Murat Gigin, chairman of Turkey's Tekfen, a memorandum was signed for the construction of a new ammonia-urea plant in Azerbaijan. Based on experience gained in the construction of the existing SOCAR urea plant, the company is looking at a second train with a capacity of 1,200 t/d of ammonia and 2,000 t/d of urea. The memorandum also provides for cooperation in the marketing of existing and new fertilizer products. The two companies will now set up a joint working group to look at issues regarding the construction of the new plant, including possible participation of Tekfen affiliates in EPC (engineering, procurement and construction) of the plant; marketing of the plant's offtake by Toros Tarım, Tekfen's subsidiary; and the participation of both parties as shareholders.

MEXICO

Public consultation on Topolobampo fertilizer plant

Mexico's president López Obrador has said that although a state investigation will determine whether the proposed new fertilizer plant at Topolobampo in Sinaloa state will "harm or benefit citizens," he will leave the final decision on the matter to a public consultation. The new plant is designed to produce 770,000 t/a of ammonia and 700,000 t/a of urea for the Mexican domestic market, and construction began on the $5 billion in August 2018 following the 2017 reversal of a federal environmental protection agency ruling to prevent the plant from operating. However, it continues to be dogged by controversy; a judicial ruling in November 2018 stopped work again after indigenous Yoreme people living in the region accused the developers of neglecting to consult and inform them about the project, as mandated by law. In March 2019, a federal judge issued another suspension order over possible effects of the plant on the Santa María, Topolobampo and Ohuira lagoons. Developer Gas y Petroquímica de Occidente (GPO), insists that it has complied with all the requirements of the law.

AUSTRALIA

Gas supply deal leads to reprieve for Gibson Island

Incitec Pivot says that it will keep its Gibson Island fertiliser plant open until at least the end of 2022 after signing a new gas supply deal. Australia Pacific LNG will supply gas to the Queensland plant, near the Port of Brisbane, from April 1st, 2020 until December 31st, 2022. Incitec has also signed a three-year extension to an existing gas supply agreement with APA Group, until January 1, 2023. Incitec Pivot chief executive Jeanne Johns said the Queensland government had taken significant steps to resolve current gas market issues, including through its domestic-only gas policy initiative. The company had previously threatened to close the facility at the end of 2019 if an affordable gas price arrangement could not be arranged. Also at stake was a major A$60 million overhaul of the plant with a two month turnaround to finish work set for 2020.

Ms Johns commented; "We are pleased that, with the support of the Queensland

government, we have been able to partner with Australia Pacific LNG, and our longstanding gas transport provider APA Group... to obtain affordable gas to continue to operate the Gibson Island plant."

UZBEKISTAN

New fertilizer complex for Uzbekistan

thyssenkrupp Industrial Solutions (TKIS) will partner Cyprus-based Ferkensco Management Ltd in the development of a new fertilizer complex in Uzbekistan's Samarkand region. Land owned by JSC Samarkandkimyo, has been set aside for the complex, which is planned to include ammonia, urea, ammonium sulphate, melamine and ammonium phosphate production. It is anticipated that most of the complex's output will be used domestically, but with the option for increased exports. The move follows a push by Uzbekistan's president Shavkat Mirziyoyev to monetise the country's domestic gas production for fertilizer production.

UKRAINE

Report on alleged monopoly abuse by Group DF

Ukrainian news agency Inferfax-Ukraine says that the Anti-monopoly Committee of Ukraine has established the facts relating to possible abuse of its monopoly by nitrogen fertilizer producer Group DF, owned by Dmytro Firtash. The committee is said to have sent its preliminary conclusions on the results of the investigation to four companies in the group, including three nitrogen fertilizer plants and NF Trading Ukraine. It argues that the group has "signs of a monopoly position on the national market for the primary sale of nitrogen mineral fertilizers". It alleges that Group DF's companies purchased natural gas for ammonia production from related companies and re-sold it at a higher price inside the group, leading to an increase in the cost of nitrogen fertilizers. Group DF producers also stopped production during 2017 due to lack of payment for gas supplies, which the Committee argues was an "artificial restriction of fertilizer production". Dmytro Firtash has long been under fire from Ukrainian authorities for his links to Russia, especially the RosUkrEnergo joint venture with Gazprom. He is also facing extradition to the USA as an associate of jailed former Trump aide Paul Manafort.

PHOTO: EUROCHEM

Eurochem's new blending plant, Araguari, Brazil.

BRAZIL

New blending plant

EuroChem Group has opened of a third fertilizer blending plant in Brazil, at Araguari in Minas Gerais state in the southeast of the country, via its subsidiary Fertilizantes Tocantins (FTO), which owns a major fertilizer distribution business in Brazil. The new plant will produce up to 6,000 t/d of blended fertilizer, with a storage capacity of 100,000 tonnes. The Araguari site also has a direct rail connection from the Atlantic seaport of Vitoria, 520km northeast of Rio de Janeiro, facilitating deliveries to local customers of specialty fertilizers produced by EuroChem in Europe, including Nitrophoska®, CAN, and NPS.

"Brazil is an important growth market for us and our new plant at Araguari marks the latest stage of our expansion in Latin America" said Petter Ostbo, chief executive of EuroChem. "I'm delighted by the progress we are making here and we will continue to provide high quality fertilizers to our growing customer base."

"The Araguari plant marks our entry into the south-eastern region of Brazil, a strategically important part of the country" said FTO's CEO, José Eduardo Motta. "After the opening of two other major plants within the past year, at Sinop and Catalão, our focus is now on the consolidation of these new markets, so we can continue to maintain our successful rate of growth."

FTO sold more than 1.8 million t/a of fertilizers in 2018, making it one of the biggest fertilizer providers in Brazil. In addition to Araguari, Catalão and Sinop, FTO has six other plants located in Porto Nacional, São Luis, Querência, Rondonópolis, Barcarena, and Anápolis, with a corporate office in Goiânia.

CHINA

New melamine plant

Chinese-based JAMG Group subsidiary Shanxi Jinfeng Coal Chemical Co., Ltd. has signed a cooperation agreement with Eurotecnica Company for the implementation of 60,000 t/a melamine project. The new brownfield melamine complex is the third award in a row for a single-reactor/single-purification plant of this size for Eurotecnica, and the fifth based on the 4th generation Euromel® melamine process.

Alberto De Amicis, CEO of Eurotecnica, commented: "We are honoured to work together with Shanxi Jinfeng Coal Chemical Co., one of the most important coal and chemical conglomerates in China and the world. This major project further strengthens Eurotecnica's market position in Asia."

Syngas News

RUSSIA

Memorandum of understanding on new methanol plant

During the St. Petersburg International Economic Forum, Gazprombank and Maire Tecnimont signed a memorandum of understanding on financing the implementation of several oil, gas and petrochemical projects in Russia and the CIS. Additionally, Maire Tecnimont, via its subsidiary MET Development, signed a memorandum of understanding with Russia's SAFMAR Group - which includes major Russian oil-producing and refining companies such as Rosneft, Neftisa, and Forteinvest – and New Gavan, the owner of the "Novaya Gavan" sea terminal. This MoU concerns the development, finance, construction, maintenance and operation of a new greenfield methanol plant for the port of Ust-Luga, 110km west of St. Petersburg. The projected methanol plant would have a capacity of 5,000 t/d, and total investment cost for the project is preliminarily estimated to be in excess of euro 1 billion. The parties agreed to discuss a joint development agreement to progress the front-end engineering design under the coordination of Tecnimont and a Russian design institute. In parallel, the parties intend to set-up a joint venture development company and will closely collaborate in the project structuring activities in order to raise non-recourse project financing. The parties intend to raise financing from international banks with the support of one or more export credit agencies.

Saudis mulling involvement in methanol project

Saudi Arabia is considering investing in methanol production in the Far East of Russia, according to a statement by Saudi energy minister Khaled al-Faleh. Mr al-Faleh was speaking at the sixth meeting of the Russian-Saudi Intergovernmental Commission on Trade, Economic and Scientific-Technical Cooperation in June. The methanol project is reportedly a 1 million t/a proposal for a plant in the Amur region, based at an oil terminal and railway junction in Skovorodino near the Chinese border. China is a major methanol consumer and the plant would presumably be looking to export across the border. Current financing for the plant stands at 49 billion rubles ($766 million), including $77 million of government funding, but developer Tehnoleasing is still looking for equity partners to provide the rest of the financing, and several Saudi companies are said to be interested in participating.

CANADA

Nauticol agrees to buy land for methanol plant

Nauticol Energy has entered into an agreement with the county of Grande Prairie, Alberta, to purchase land for a proposed C$2 billion methanol plant 10 km south of the town of Grande Prairie itself. The county plans to buy the land from the government of Alberta and then sell it to Nauticol for a price yet to be determined. The province cannot sell the land directly to Nauticol as it currently legally leases it from the province government.

Mark Tonner, president and CEO of Nauticol, stated that the company was "delighted" to work with the county for this land purchase. "Each step we take down the path means we're going to get that much closer to the construction and operation of the plant," Tonner said. "We're really excited about this milestone and what it means in advancing the project, so we couldn't be happier with the region of Grande Prairie."

Nauticol is looking to initially develop a 1 million t/a methanol plant, although the company has talked about two further potential units in the longer term. The first plant is due to begin construction in 2020, with completion in 2022. Regulatory and licensing approvals are still pending.

DENMARK

Low carbon methanol production

Researchers from Haldor Topsoe have partnered the Technical University of Denmark, the Danish Technological Institute, and metallurgical company Sintex to propose a low carbon route to methanol production, detailed in a recent article in Science magazine. The researchers suggest that as much as 1% of global CO_2 emissions can be saved if compact, electrically-based technology is used in the syngas industry. The research team has used computer simulations and lab testing to show that direct electric heating in combination with an innovative thin catalytic coating boosts both energy efficiency and catalytic efficiency. The improved efficiency saves CO_2 in itself, but the real gain comes from replacing natural gas with electricity for heating the process to the 900°C necessary to drive the reaction, reducing carbon emissions from syngas generation by up to one third – potentially representing up to 1% of the world's total carbon emissions. The electricity is assumed to come from low carbon sources such as wind turbines or solar panels. The technology also allows the rector to retain efficiency even when scaled down significantly.

"We see the electrified reactor as the next logical step for the chemical industry. With this approach, producers get a viable way to transform the industry going towards greener processes without increasing production cost," said Peter Mølgaard Mortensen, principal scientist, Haldor Topsoe.

Topsoe launches connected service for hydrogen plants

Haldor Topsoe have followed their March launch of their *ClearView*™ Ammonia service with the launch of a comparable *ClearView*™ Hydrogen service; a complete connected plant service which leverages the power of continuous upload of data to offer plant owners improved asset utilisation, energy savings, and less unplanned downtime. Based on a stream of comprehensive data from the plant, modelling and analytical software proactively alerts plant personnel of operational issues and continually suggests optimisation opportunities. The insights are produced by applying Haldor Topsoe's unique tools and experience to validated operating data from the plant, using Honeywell's cloud-based software platform and tools.

"Reliable hydrogen production is a critical production parameter for refineries. So we are extremely pleased to offer our customers a service that puts our decades of experience at their fingertips every hour of every day. *ClearView*™ applies Topsoe's unique insights and allows our experts to

work more closely with plant engineers to meet critical performance targets and reduce the risk of unplanned shutdowns," said Michael Fjording, director, Connected Services, Haldor Topsoe.

GERMANY

BASF develops zero-CO_2 process for methanol

BASF researchers say that they have developed a process to produce methanol without any greenhouse gas emissions. The process generates syngas by partial oxidation of natural gas, followed by methanol synthesis and distillation. Key however is treatment of the waste gas streams that arise during methanol synthesis and distillation and which cannot be avoided even with optimal process management. These waste gas streams – consisting of methane, carbon monoxide, carbon dioxide and hydrogen – are incinerated in an oxyfuel process with pure oxygen. This results in a small volume of flue gas with a maximum carbon dioxide content. The flue gas is then scrubbed using BASF's OASE process for recovery of the carbon dioxide. The captured carbon dioxide is fed back into the process, but requires additional hydrogen to convert it to methanol. BASF aims to generate this hydrogen without any carbon dioxide emissions, for example, via methane pyrolysis.

"We are optimistic that our climate-friendly approach will better adapt methanol synthesis to the requirements of the 21st century," said project manager Dr. Maximilian Vicari from BASF's Intermediates division. "Nearly 100 years after the first industrial-scale production of this important basic chemical using BASF's high-pressure process, we are now taking a leading role in writing the newest chapter in the history of methanol." Vicari said that he expects it will be around 10 years before this new process has been scaled up to an industrial-scale plant.

IRAN

Kaveh methanol plant starts up

The Kaveh Methanol Company has reportedly begun production at its 7,000 t/d methanol plant at Dayyer in the southern Iranian province of Bushehr. The facility is the largest single train methanol plant to have been constructed in the world. It was licensed and designed by Casale, and constructed by Iran's Petrochemical Industries Design and Engineering Company (PIDEC). Ground was broken for the construction of the Kaveh methanol plant as long ago as 2004, but international sanctions meant that Iran could not purchase and ship the necessary equipment items until 2014. The plant uses autothermal reforming, and also features the world's air separation unit, with a capacity of 120,000 Nm^3/h, including the world's largest air compressor and three tanks for liquefied oxygen, argon and liquefied nitrogen. There are also two 50MW steam turbine power plants and a 55MW gas power plant, four water desalinators, 14 diesel-fuelled generators, seven boilers, and seawater pumping station.

Methanol tanker crippled by "mine"

On June 13th the methanol tanker *Kokuka Courageous*, operated by Mitsubishi Gas Chemicals, was crippled by what is reported to be a mine while sailing in the Gulf of Oman, 25 km from the Iranian coast. The tanker was carrying 24,000 tonnes of methanol when an explosion occurred on board, causing severe damage to the starboard side of the hull. A similar blast also crippled the LNG

tanker *Front Altair* at the same time. Both attacks have been blamed on the Iranian government and the US claimed that Iranian patrol boats were seen in the vicinity of the two vessels, planting limpet mines, although the operator of the *Kokuka Courageous* said that the crew had reported 'flying objects' before the blast.

The *Kokuka Courageous* had loaded methanol from Saudi Arabia and Qatar and was bound for Singapore and Thailand to supply Mitsubishi petrochemical subsidiaries. MGC is reportedly looking at securing methanol from its Brunei Methanol Company plant to cover for the shipment to customers.

MALAYSIA

Hydrogen fuelling station launched

Southeast Asia's first integrated hydrogen production plant and refuelling station has been officially opened in Sarawak, the Malaysian part of the island of Borneo, in a ceremony attended by Chief Minister Datuk Patinggi Abang Johari Openg. The hydrogen electrolysis unit will fuel Sarawak's fleet of hydrogen fuel cell buses, owned and managed by the Sarawak Economic Development Corporation (SEDC). Construction and operation of the plant and refuelling station was undertaken by state-owned power provider Sarawak Energy Berhad in collaboration with Linde. The chief minister said the state government is supporting the emission-free vehicle programme which is part of its long-term plan in ensuring that the public transportation system is operating on clean energy.

UZBEKISTAN

Uzbekistan to build MTO unit

Uzbekistan's Ministry of Energy has signed a project development agreement to build a new methanol-to-olefins (MTO) plant with a group of investors including Uzkimyosanoat, Air Products & Chemicals, Uzbekneftegaz and Enter Engineering. Haldor Topsoe will provide the methanol license and Honeywell UOP the MTO technology. Amec Foster Wheeler have been engaged as technical consultants on the project and IHS Markit on the market side. The agreement envisages a 500,000 t/a olefins unit.

Uzbekistan Minister of Energy Alisher Sultanov said: "The decision to build this plant is another step to drive Uzbekistan's petrochemicals growth strategy and continue on the path of increasing exports of value-added products, as well as raw materials. This project will help to build Uzbekistan's competitiveness as a player on the international stage."

In a joint statement, the investors said: "We are delighted to take the first step in supporting a new petrochemical plant in Uzbekistan. As a group of investors, we are keen to support projects that offer a positive return on investment whilst also being strategically attractive for the country of Uzbekistan."

"This project will help to build Uzbekistan's competitiveness as a player on the international stage."

PHOTO: HALDOR TOPSOE

Topsoe modular CO unit.

NORWAY

Explosion at hydrogen fuelling station

A hydrogen fuelling station in a suburb of Norway's capital Oslo has exploded. Nel Hydrogen, the parent company of operator Uno-X, said that the fire was contained within three hours. Two people were sent to hospital due to an airbag triggered by the explosion in a nearby car. Nel operates 50 hydrogen fuelling stations in nine countries, and shut down 10 of these across Denmark and Norway following the incident for safety checks. According to the company's initial investigation, hydrogen gas that had leaked caught fire in the open air, creating a pressure wave. Japanese carmaker Toyota and South Korea brand Hyundai both halted sales of hydrogen-powered fuel-cell vehicles in Norway after the incident. The explosion came a week after an explosion at an Air Products hydrogen plant in Santa Clara, California, during fuelling of a tanker truck, which disrupted supplies to hydrogen fuelled vehicles in southern California.

UNITED STATES

DeLille Oxygen Co. leases two units for on-site CO production

Speciality gas company DeLille Oxygen Co. has agreed to lease two of Haldor Topsoe's eCOs™ on-site carbon monoxide generation systems to produce ultra-high purity CO for a customer in the isotopes labeling industry. One unit will be sited at DeLille's customer's site for reliable and flexible over the fence delivery of CO, while the other will deliver on-demand CO for the rest of DeLille's customers from the company's headquarter in Columbus, Ohio. The new units produce carbon monoxide via carbon dioxide electrolysis will have a capacity of 96 Nm^3/h (3,650 scf/h) of CO and are expected to be commissioned in summer 2020. The units are modular which ensures a small footprint and fast installation. The lease and service agreement includes operational optimisation and electrolysis maintenance and training of operators.

UNITED KINGDOM

Waste gasification demonstration plant starts producing syngas

A waste gasification plant has started up in Wednesbury in the UK Midlands. Backed by the Energy Technologies Institute (ETI), the 1.5MW Waste Gasification Commercial Demonstration Plant has been built at the Sustainable Energy Centre in Wednesbury in partnership with Kew Technologies. Wood-derived syngas will be used for initial testing, before a switch to around 40 t/d of post recycling, refuse derived fuel (RDF) as a feedstock. ETI says that the plant has started to produce syngas "at a quality exceeding initial predictions". Once fully operational, the waste gasification plant will provide enough electricity to power 2,500 homes. ■

People

EuroChem has announced the election of **Petter Ostbo** to the company's board of directors. Mr. Ostbo, who joined the company as Chief Executive Officer on June 1st, previously served as EVP and Chief Financial Officer of Yara International, before which he held the position of EVP Production at the same company, with responsibility for 28 production sites and four mines in 16 countries. Separately, former CEO **Dmitry Strezhnev**, who served as a board member for more than 15 years, has stepped down from the Board after deciding not to stand for re-election and to focus instead on other business ventures outside EuroChem.

"We are delighted to welcome Petter to the company's board. He has a wide range of experience and is highly regarded in our industry," said Alexander Landia, chairman of the board of EuroChem. "I am also grateful to Dmitry for his long service to EuroChem. He has been instrumental in the successful development of the company into a global force in the fertilizer industry and we wish him every success in the future."

IHS Markit has announced the exchange of the majority of the IHS Markit Technology, Media and Telecoms (TMT) intelligence business for Informa's Agribusiness Intelligence group.

"This agreement is very positive for both IHS Markit and Informa, increasing the focus of each company on core markets where it has particular strengths and a long-term commitment to invest and grow," said Lance Uggla, CEO of IHS Markit and Stephen A. Carter, Group Chief Executive, Informa PLC.

PHOTO: INGAR SØRENSEN

Petter Ostbo.

"The Informa Agribusiness Intelligence portfolio is a clear extension of our Chemical and Downstream businesses and builds our existing data, pricing, insights, forecasting and news services within our Resources segment," continued Uggla. "Agriculture is the largest end chemical market in the world and this transaction expands our capabilities into fertilizers and chemical crop protection, while substantively expanding our capabilities in biofuels."

The agreement values the two exchanged businesses at equivalent EBITDA multiples, with Informa contributing an additional $30 million cash to IHS Markit to reflect the larger EBITDA contribution from the TMT business. IHS Markit will retain RootMetrics, its benchmarking business and a portion of its market intelligence business. Both transactions are expected to close in July 2019 and are subject to customary closing conditions, including US regulatory approval.

Haldor Topsoe scientist **Stig Helveg** has received the prestigious 2019 Innovation in Materials Characterization Award for his pioneering work on atomic-scale transmission electron microscopy under reactive gas environments, leading to ground breaking insights in catalysis, crystal growth, and corrosion. The Innovation in Materials Characterization Award is awarded by the esteemed Materials Research Society (MRS). It honours experts whose outstanding advance in materials characterization has increased knowledge of the structure, composition, in situ behaviour under outside stimulus, electronic behaviour, or other characterisation feature, of materials.

"When we started this work 20 years ago, it was a daring experiment. We wanted to learn more about catalysts, but it wasn't a given that we would succeed and overcome major obstacles and develop brand new ways for operating electron microscopes. Now, it has become a whole research field in itself and people are building further on our knowledge," said Stig Helveg. "At Topsoe, we have a great environment for innovation and we're good at figuring out new knowledge and exploit it in R&D; the prize is just one example. I am truly honoured and proud to receive the award but I'm getting it on behalf of many talented colleagues who have contributed to this research over the years. The award is a tribute to their effort and I am just part of it." ■

Calendar 2019

JULY

16-19

Internat'l Methanol Technology Operators' Forum (IMTOF) 2019, LONDON, UK
Contact: Polly Murray, Johnson Matthey
Email: polly.murray@matthey.com

SEPTEMBER

8-12

64th AIChE Annual Safety in Ammonia Plants and Related Facilities Symposium, SAN FRANCISCO, California, USA
Contact: AIChE Customer Service
Tel: +1 800 242 4363/+1 212 591 8100
Fax: +1 212 591 8888
Email: xpress@aiche.org

8-13

Ammonium Nitrate/Nitric Acid Conference, VIENNA, Austria
Contact: Hans Reuvers, BASF
Karl Hohenwarter, Borealis
Email: johannes.reuvers@basf.com
karl.hohenwarter@borealisgroup.com
Web: www.anna-eu.com

23-25

TFI World Fertilizer Conference, CHICAGO, Illinois, USA
Contact: Valerie Sutton, The Fertilizer Institute, 425 Third Street, S.W., Suite 950, Washington D.C. 20024, USA.
Tel: +1 202 962 0490
Email: vsutton@tfi.org

24-26

GPCA Fertilizer Convention 2019, MUSCAT, Oman. Contact: Anida Dcosta, Conference Producer, GPCA
Tel: +971 4 4510666
Email: anida@gpca.org.ae

OCTOBER

27-29

Nitrogen+Syngas Middle East, MUSCAT, Oman
Contact: CRU Events
Tel: +44 (0) 20 7903 2444
Fax: +44 (0) 20 7903 2172
Email: conferences@crugroup.com

27-29

Global Syngas Technologies Meeting, AUSTIN, Texas, USA
Contact: Global Syngas Technologies Council, 3030 Clarendon Blvd. Suite 330 Arlington, VA 22201 USA.
Tel: +1 703 276 0110
Fax: +1 703 276 0141
Email: info@gasification-syngas.org
Web: www.gasification-syngas.org

Plant Manager+

Problem No. 55 How to clean heaters

Heat exchanger tubes in heaters in a urea plant such as the high pressure stripper and medium pressure and low pressure recirculation heaters typically suffer from process-side fouling. This fouling can be caused by oil and/or iron and chromium oxides. One obvious solution to remove this fouling is high pressure water jetting, but the fouling in the high pressure stripper can be so hard that this method does not work.

Stamicarbon together with VECOM, in the Netherlands, have developed a chemical cleaning method for cleaning CO_2 strippers, and NIIK, in Russia, has developed and successfully applies several cleaning methods for the removal of scale in heat exchangers in urea plants such as thermo-abrasive blasting, hydromechanical cleaning, high pressure hydro cleaning, vortex blasting cleaning, chemical cleaning (with ortho-phosphoric acid, and ultrasonic cleaning.

Mark Brouwer of UreaKnowHow.com in the Netherlands starts the round table discussion: Heaters can be fouled with oil and scale from corrosion products. What, according to your experience, is the best way to clean these heaters?

Waqqar Ahmed of Fauji Fertilizer in Pakistan replies: In Fauji Fertilizer we use different techniques for cleaning exchangers but the most common and effective one is high pressure water jetting. Last year in our turnaround of March 2008 we also carried out tube cleaning with scraper bullets (CTI) for the first time, which was also satisfactory.

Mark has some further questions: What does CTI stand for? How do you clean the high pressure stripper, medium pressure and low pressure heater?

Waqqar replies: Normally no scale deposits are observed in the high pressure stripper so we do not clean it. For the medium pressure and low pressure heaters we use high pressure water jetting. CTI is just the trade name of the cleaning solution providers.

Muhammad Adnan Hanif of Fauji Fertilizer in Pakistan joins the discussion: In my opinion chemical cleaning under a controlled acid concentration environment is the most effective way to overcome fouling problems due to oil and scaling of corrosion products rather than high pressure water jetting and mechanical cleaning. However, it is a difficult task and specialised job due to the highly corrosive nature of the chemicals used.

In our last annual plant maintenance shutdown, for the first time we cleaned the CO_2 absorber packing (made of stainless steel) with acid under controlled concentration and its performance compared to mechanical cleaning was much better.

We have also tried using the same technique to clean one of our stainless steel compressor intercoolers (cooling water side) and again the performance was quite good.

Therefore, I prefer chemical cleaning of lube oil coolers over higher pressure water jetting.

Waqqar comments further: I agree, chemical cleaning under precise controlled conditions is very effective. But to use the same for medium pressure/low pressure heaters and high pressure stripper cleaning will be extremely difficult due to the nature of the deposits (contains mainly hematite Fe_2O_3) and conditions to dissolve the deposits. It also does not seem economically justified for such equipment items.

At Fauji's Plant-II, "VECOM", a specialist in maintenance and surface treatment was contacted for the removal of such hard deposits. After analysing the sampling and lab results they were of the opinion that complete deposit removal cannot be guaranteed.

Fabiano Parizotto of Petrobras shares his experiences: We need to clean our high pressure stripper at least once a year. We usually clean it by high pressure water jet and then check the results using a caliper.

If the result is unsatisfactory, we can decide whether to try chemical cleaning procedure in the next turnaround.

To clean up deposits in the tubesheet we use do it manually if the high pressure water jet does not result in a clean enough surface.

Waqqar makes an interesting observation: In our March 2008 turnaround, very hard and thick black deposits were observed on the top tube sheet of our urea stripper. We tried to remove the deposits through high pressure water jet and mechanical means. But to avoid any damage deposits were left as such.

Before shutting down the plant for the turnaround, we were facing a low N/C ratio problem due to certain limitations. After the turnaround the N/C ratio was strictly maintained above 3.25. The plant was again shut down in September and the thick deposits were found to have dissolved and only minor deposits were present.

Ahmed Selim of AlexFert in Egypt joins the discussion: Can you elaborate about your experience for cleaning stripper tubes (especially the bottom part) after more than ten years of operation knowing that it was never cleaned mechanically before. Can it just be cleaned with a water jet pump once or twice?

Are you using a caliper to check the remaining thickness of tube after cleaning?

Do you think the N/C ratio has an effect on dissolving such deposits?

Mark replies: VECOM and Stamicarbon have together developed a chemical cleaning procedure for CO_2 strippers in which in the bottom part of the tubes a very hard iron- and chromium-oxide scale will typically form after several years of operation. The chemicals used are a mixture with, including, EDTA. The cleaning takes place at a certain temperature. It is a batch process and the efficiency can be checked and controlled.

The same scaling will happen in the low pressure heater of the Stamicarbon plant, but experience has shown that with high pressure water jetting one can remove this. One needs to remove the orifice plugs to enable proper cleaning.

In Fauji we talk about a hard black scaling on top of the tubesheet of the NH_3 stripper. This is different from what VECOM normally sees which is why I think they cannot provide a guarantee in that case.

If the back colour is coming from oil, it can be an issue. The EDTA cleaning procedure does not work properly when oil is present and also in case of oil fouling, oil should first be removed.

Tarek Sadek of AlexFert in Egypt joins the discussion: What if the orifice plugs themselves are plugged with these hard deposits decreasing their diameter, what is the best way to clean the tubes of the low pressure heater?

And do we have in this case to remove orifice plugs for efficient cleaning?

Is a sand blasting technique efficient in such a case?

Mark replies: It is best is to remove the orifice plugs as they hinder high pressure water jetting. I have no experience with sand blasting but would be careful not to damage the tubesheet. ■

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.

Ammonia rail tank car in Russia.

PHOTO: UWC

Preventing ammonia leaks

Many casualties and fatalities at nitrogen plants are caused by leaks of ammonia, often due to corrosion or issues during storage or transport. What steps can be taken to minimise the risk from accidental ammonia releases?

Ammonia is produced in large quantities; globally, it is the second largest chemical in terms of production. Even though most ammonia is produced for captive, downstream use, mainly for production of urea or nitric acid (the latter mainly for ammonium nitrate), an average plant produces more than 1,000 t/d, and considerable volumes of ammonia are often stored on-site at such plants. Large volumes of ammonia are also transported, sometimes long distances, by pipeline, rail, barge or ship. As well as the hazard that ammonia leaks pose to plant personnel and transport staff, ammonia producing plants are also often sited near major centres of population, while pipelines, storage tanks and of necessity road, rail and river connections also pass close to populated areas, and hence pose a risk during transport.

The hazards that ammonia releases can pose can be seen in a number of recent incidents. In December 2018 an ammonia leak at Litmus Organic Pvt Ltd hospitalised 14 people at Ratnagiri in India's Maharashtra state, 330 km from Mumbai, while in April 2019 near Chicago a leak from a vehicle transporting ammonia hospitalised 38 people, including 14 first responders, and five were taken to intensive care.

Ammonia hazards

There are chiefly two hazards associated with ammonia. The first is irritation of soft tissues of the body. Ammonia is highly alkaline and reacts with water to form corrosive ammonium hydroxide. This can be particularly serious in contact with the eyes or lungs. Lower concentrations in air cause eye and respiratory irritation, coughing, and wheezing. Concentrations of 300 parts per million (ppm) or greater are classified as 'immediately dangerous to life or health' (IDLH). Fortunately ammonia is detectable by most people at levels from as low as 5 ppm, which can assist with taking evasive

action. However, where a high concentration is encountered suddenly, it can overcome people. At 400-700 ppm severe eye and respiratory irritation can occur, and at 1,700 ppm convulsive coughing and bronchial

spasms occur, with 30 minutes exposure to this concentration being potentially fatal. Exposure to high concentrations (above 2,500 ppm) are life threatening. The US OSHA short term exposure limit is 50 ppm over 15 minutes, and time weighted average 20 ppm over eight hours.

Direct contact with liquid ammonia – ammonia is stored as a liquid at -33°C or below – can also cause frost burns.

The second major hazard associated with ammonia is fire and explosion, especially in an enclosed space or when other flammable chemicals are present. Ammonia is combustible but difficult to ignite, with an auto-ignition temperature as high as 650°C. It also requires a high concentration in air to reach its lower explosion limit (16%), which tends to be difficult to achieve as it often disperses – indeed, a survey published in the International Review of Chemical Engineering[1] noted that to date (2010) there had been no recorded ammonia explosion incident in open air conditions. One of the reasons for this is that ammonia is lighter than air and so tends to rise. For this reason, venting of ammonia to air can usually be conducted safely during emergency situations and plant upsets. Recent testing by Baker Risk, reported at the 2017 AIChE Ammonia Safety Symposium[2], found that even when ammonia vapour cloud explosions in open air could be initiated (the testing used a 23% mix of ammonia in air), damaging blast loads would not be expected due to the low flame speeds generated. In confined spaces, however, ammonia can build up to an explosive ammonia-air mixture more easily and can pose a potential explosion hazard.

Corrosion

For the purposes of leaks, ammonia's high alkalinity in water can also make it corrosive to metal equipment. Alloys of copper and zinc are especially susceptible and should not be used where they might come into contact with ammonia. Ammonia can also embrittle iron and steel which can then lead to structural failures of pipes or containment vessels. Stress corrosion cracking can occur if ammonia is in contact with oxygen to any degree, although this can be ameliorated by the presence of water.

Storage

Ammonia is usually stored as a liquid in refrigerated tanks at -33C and atmospheric pressure, often in doubled-walled tanks with a capacity of several hundred to several thousand or even tens of thousands of tonnes. The low temperature is maintained by the venting of ammonia gas, lowering pressure and temperature, with the ammonia gas recycled back to refrigeration. The American Petroleum Institute (API) standard 625, Tank Systems for Refrigerated Liquid Gas Storage addresses the main concerns to be taken into account in the construction of storage tanks for liquid ammonia. Ammonia storage are commonly surrounded by an earth or concrete bund wall to keep any large scale spillage or leak of liquid ammonia within a prescribed area and limit the surface area available for evaporation. Evaporation can further be slowed by blanketing an ammonia release with foam.

Tanks can be either single or double walled. The choice of which route to take should be based on a risk assessment of the potential volume and speed of ammonia release and the consequences to plant personnel and surrounding areas. Siting of storage tanks near populated areas can be a vexed issue as regards permitting by local authorities. The siting of an ammonia storage tank belonging to Haifa Chemicals at the port of Haifa in Israel led to a long-running legal battle between the local authority and the company which eventually led to the storage tank being shut down. In Europe, siting of ammonia storage of more than 50 tonnes falls within the Seveso II requirements for land use planning with respect to major accident hazards. Article 9 of this directive requires the operator to prepare on-site and off-site emergency plans and to produce a safety report.

Periodic inspection of storage tanks is very important and inspection frequency to be increased in case of older vessel. Sometimes uneven settlement of the tank foundation after long period increases the stress and results in stress corrosion cracking (SCC). Stress corrosion cracking has been detected in some liquid ammonia storage tanks operating at -33°C and in some ammonia pressure spheres operating at ambient temperatures. The presence of water inhibits the formation and growth of SCC – in the US it is usual to make sure that liquid ammonia contains at least 0.2% water for this reason. Fertilizers Europe has produced a set of guidelines for the risk-based inspection of ammonia storage tanks[3]. Appropriate exercises (test drills) should also be carried out to test emergency plans at suitable intervals, in conjunction with the relevant emergency services and authorities, using ammonia release scenarios applicable to the installation. The plans should be reviewed and improved based on the lessons learnt from such exercises.

Accidental release during operation

Most ammonia releases occur during normal handling operations. The US Operational Health and Safety Administration (OSHA) has issued general guidelines for preventing accidental ammonia releases during normal handling operations as part of its standard 1910.111, Standard on the Storage and Handling of Anhydrous Ammonia[4]. These include recommendations to: develop and maintain a written operational and preventive maintenance program; require all maintenance personnel and operators to follow written, standard procedures for operating and maintaining the system at safe limits; and ensure that the ammonia refrigeration system is operated and maintained only by trained and competent personnel.

Releases can occur during ammonia shutdown operations while workers are opening and draining process equipment, locking out equipment for maintenance, or blocking liquid ammonia lines and equipment – especially equipment that contains ammonia liquid that is below ambient temperature.

To prevent releases, OSHA recommends that facilities look closely at ammonia relief systems, making sure they are designed and installed according to generally accepted good engineering practices. Workers should have detailed written procedures and thorough training that covers opening and draining process equipment, and blocking liquid ammonia lines. Any accident or near miss that could have resulted in a release of ammonia should be investigated and any identified issues addressed. In case of release, an emergency action plan should be established and implemented.

Transport – pipelines

Ammonia is transported by pipeline around facilities, and some longer distance ammonia pipelines also exist. Fertilizers Europe estimates in its best practice guidelines for ammonia pipeline inspection and leak detection[5] that there are 5,000 km of long distance mild steel ammonia pipeline in

operation in the US, handling over 2 million t/a of ammonia, concentrated in the Gulf of Mexico, Florida and the mid-West. There is a long (>2,400 km) pipeline connecting Russian production to the port of Odessa. The EU has relatively fewer pipelines and these cover shorter distances.

A survey of ammonia pipeline incidents quoted in the same guidelines found that most were due to corrosion, fatigue cracks or seam failure, with overpressure and maintenance work other causes.

External corrosion can be inhibited by a suitable paint/coating for carbon steel. Stainless steel is generally not coated unless in a highly corrosive environment (eg maritime areas). Buried pipelines must be coated to control external corrosion, with e.g. bitumen, polyethylene or polyurethane. Moisture in and under insulation may also cause external corrosion of carbon steel pipelines.

Pipe clamps and welded joints are particularly susceptible to corrosion. Thermal insulation between a cold pipeline and support clamp reduces the incidence of cold spots and ice formation. Direct contact between a stainless steel pipeline and a carbon steel support structure should be avoided to prevent corrosion of the support.

Internal corrosion is mainly caused by stress corrosion cracking (SCC). Welds can again be especially vulnerable if oxygen is present in sufficient quantities. Cathodic protection is essential for the effective corrosion protection of underground and submerged pipelines.

Other hazards around pipelines concern mechanical damage. Digging operations near buried pipelines can of course be a source of incident, and all pipelines must be properly marked by line markers – on poles above buried pipelines – and warning signs. Above ground pipelines must be clearly identified to avoid, eg vehicles that are too tall trying to drive under them – a minimum height of 5m is recommended, and vulnerable sections need crash barriers and can be monitored by CCTV cameras.

Other recommendations include thermal relief valves to prevent ruptures and leaks caused by thermal expansion of the liquid, and pipes and pipe racks must be provided with electrical grounding as a protection against electrical fault conditions, lightning and build-up of static electricity, as well as to provide protection against welding currents interfering with the connected rack or piping system.

Fertilizers Europe recommends that liquid ammonia pipelines be fitted with isolation valves, preferably remotely operable, and failing safe in the event of power failure, at suitable intervals to limit the loss of ammonia in the event of a pipeline failure. US practice is to have a maximum volume of 400 tonnes between isolation valves, EU practice tends to smaller volumes.

As with the OSHA notes on ammonia hazards during normal operations, when commissioning or decommissioning pipelines, a pipeline containing air should ideally be purged with nitrogen prior to introducing ammonia in order to avoid the formation of potentially explosive ammonia/air mixtures. Also, sending the ammonia/air mixture to storage facilities is undesirable because of the possibility of stress corrosion cracking that can occur when oxygen is present in ammonia storage tanks. A pipeline should be cooled down and warmed up slowly to prevent thermal stresses.

Emptying a pipeline containing liquid ammonia should be carried out by expelling the liquid ammonia with a gas, preferably ammonia vapour. Purging the liquid ammonia line with nitrogen can result in the formation of extremely low temperatures for which the line might not have been designed.

Regular (weekly or monthly) visual inspection of liquid ammonia pipelines is recommended to maintain their safety and security, noting condition of any surface coating, insulation and markers, the position of isolation valves, condition of instrumentation, pipe supports and of other vulnerable parts, and condition of the safety precautions incorporated at intersections of the pipeline with roads, railroads and waterways.

Periodic inspections are recommended on specific aspects of the pipeline. Wall thickness measurements of above-ground pipelines using non-destructive methods are carried out in the EU every 1-10 years, with a typical average of 4 years. Welded joints can be inspected via radiography, magnetic particle examination or via dye penetrants every five years or so. Pipeline parts under clamps are vulnerable to corrosion and cannot be directly visually inspected, therefore, it is recommended to take a few random samples on a regular basis.

Thermal relief valves should also be periodically removed for inspection. Inspection frequency in the EU is 1-10 years, with a typical frequency of once per 4 years. For underground pipelines, inspection of the functioning of the cathodic protection should be conducted on a regular basis.

Transport – rail

Fertilizers Europe's ammonia incident database shows that of 114 incidents during production, loading and transport, 92% happened during transport and 8% during loading/unloading, with 55% represented by derailment, turn over of a rail car or its collision with another train or vehicle. Another 40% of accidents were due to flanges, valves, packing, or bad connections, although these often occasioned only a minor release. Only 5% of accidents led to a substantial release of ammonia.

Railway tank cars for transporting anhydrous ammonia must meet national design and construction regulations as well as international provisions, especially the Regulations for the International Carriage of Dangerous Goods by Rail (RID). Construction materials must be selected to minimise stress corrosion cracking. Valves need to have independent closures and shut off devices, with filling and discharge openings equipped with an instant-closing internal safety device which closes automatically in the event of an unintended movement of the shell.

RID also specifies period inspection tests. Pressurised rail tank cars for ammonia have to be subjected to a hydraulic pressure test every 8 years and a leak-proof test every 4 years, with the most recent test marked on the plate. An additional internal inspection and crack tests have to be performed every 8 years. Tank cars used for ammonia and made of fine grid steel should be tested for stress corrosion cracking.

Loading/unloading operations of tank cars should only take place in areas of the site specifically allocated for this kind of operation, suitably marked and away from hazards such as passing roads or rail lines, buildings, drains, with an interlock system to prevent other cars from entering the station during operation. A safe distance of at least 15 metres is recommended from flammable substances, and 25 m from loading/unloading of flammable liquids or gases if such activities are performed simultaneously.

Loading and unloading stations should have devices for leak detection, and suitable safety equipment, possibly including positive pressure air supply, as well as a remote shutdown system that can be used in an emergency situation and containment systems such as a water curtain. The loading/unloading of liquid ammonia may only be performed by qualified operators who

are specially instructed about their tasks. All operators should be regularly involved in practice drills for emergency response.

Loading can be done by a single operator, but loading and unloading operations should also be monitored by a second operator, either nearby or monitoring by eg video link. Appropriate protective equipment must also be worn. Checklists should be used to ensure that all safety and quality checks are performed in a standardised and reliable way. To prevent overfilling the filling weight has to be controlled by at least two independent measuring systems.

In general, all parties involved in the transport and handling of ammonia should carry out a risk analysis on all the external ammonia transport from the supplier's site to the customer's site. Transport stops, shunting etc. must be carefully considered so that effective emergency action plans can be established. Emergency action plans must contain all the steps to be taken should there be an accident or near-miss at any rail/shunting stations or during transit.

> **"Early leak detection is vital to prevent large scale loss of ammonia from a leak.**

Leak detection

Early leak detection is vital to prevent large scale loss of ammonia from a leak. Various systems are available. Escaping ammonia can be detected by ammonia sensors at various locations in an ammonia plant. They can be placed in loading and tank areas, and around a pipeline.

A mass balance system detects spontaneous changes in the mass balance of the liquid ammonia pipeline system. Upon a leak, the mass balance system usually first gives an alarm. When no operator action follows in a pre-determined period, some systems automatically close the isolation valves in the affected part of the pipeline system or in the entire pipeline system. However, there are concerns about the accuracy of such a system.

A pressure drop system can be coupled with automatic shutdown valves, but generally is sensitive only to larger releases and so needs to be used in tandem with other detection methods.

Acoustic systems have been developed which can detect leaks along a pipeline as small as 0.4 kg/m^2 within a matter of seconds, and the leak can be isolated to within 20 metres. Likewise seismic sensors along the pipeline can detect any activity which causes a seismic signal in the ground, and distinguish leaks from other seismic sources such as people, vehicles etc.

Emergency response

Ammonia gas or vapour, at ambient temperature as well as at its normal boiling point of -33°C is lighter than ambient air; consequently, any release of the vapour alone forms a buoyant plume, dispersing upwards in the atmosphere. The rate of dispersal of ammonia clouds is highly dependent of environmental conditions including wind speed and humidity. Even after large releases of ammonia, it is possible for levels of ammonia vapour in air to return to background levels within a matter of hours.

However, when liquid ammonia is suddenly released from a pressurised liquid line, part of the ammonia is vaporised. The escaping plume tends to be made up of flashed off ammonia vapour, entrained droplets of liquid ammonia and entrained ambient air. The degree of vapour flash is dependent on the temperature and pressure of liquid ammonia. Pools of cold (-33°C) liquid ammonia on the ground can be formed either as a result of rainout from the release or from spills from the line.

After an initial flash caused by the decrease in pressure and input of conductive heat from the ground, the pool gradually cools down by convective vaporisation and adiabatic saturation of air. The resulting cold mixture of air and ammonia will be heavier than the ambient air in most cases. The chilling effect produced either due to flashing or adiabatic saturation can cause visibility difficulties within the plume, particularly near the source of release a white dense fog will be formed. Water screens or curtains can prevent the spread of such an ammonia fog.

As soon as an ammonia release has been detected, measures must be taken to stop the release, if safe to do so, and to get the consequences under control.

Protection of surrounding communities

Immediate warnings must be issued when an ammonia incident has taken place whereby the escaping ammonia can affect the population. When an ammonia escape is potentially threatening, the population living downwind of the incident may have to evacuate. However evacuation takes time and that is why evacuation is often potentially unsafe or impossible.

The population living in the danger zone needs to be warned as soon as possible. They need to be advised to stay inside, close all doors, windows and ventilation openings and to use wet towels to cover openings under doors and windows. In the event of a prolonged release it may, however, become necessary to carry out evacuation.

Limiting the release

Attempts should be made to reduce the rate of escape of ammonia. When liquid ammonia escapes from a line, the pressure in the line is likely to stay constant as long as the source has liquid ammonia inventory. Since the water that is normally available to control ammonia gas clouds is warmer than the pipeline containing the cold boiling ammonia, the leaking pipeline should not be sprayed with water.

The release can be controlled by isolating the leaking part of the line, or, in case of a leaking valve or flange: repair.

Ammonia dissolves very well in water, but to effective, large quantities of water are needed. Water should not be sprayed directly into a pool of liquid ammonia unless a very large excess is immediately available.

Fighting ammonia fires should be done with dry powder or CO_2. Water sprays can be used to cool fire exposed structures, disperse vapours and protect personnel. Fire fighting personnel should wear self-contained breathing apparatus and full protecting clothing. ■

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Methanol technology and operations

Aerial panoramic cityscape view of London and the River Thames.

PHOTO: ENGEL CHING/SHUTTERSTOCK.COM

The International Methanol Technology Operators' Forum (IMTOF) was held in London from June 16th-19th, showcasing best practices and new developments.

The International Methanol Technology Operators' Forum (IMTOF), hosted bi-annually by Johnson Matthey (JM) and its antecedents in the field of methanol technology (Synetix, ICI Katalco) for more than 20 years, remains pretty much the only dedicated technology forum for methanol plant operators. Held once again in its familiar surroundings of London, it provided 100 delegates with the chance to share experiences and discus new developments in the world of methanol.

Methanol markets

Mark Berggren of CMAI presented the methanol market paper, noting that Chinese demand growth, which has driven the methanol market for the past 20 years, remains positive, but is beginning to slow as a longer period of relatively high methanol prices crimp demand into some end use applications. There are still major production increases occurring, especially in the US and Iran, which are keeping prices lower this year, but longer term there is not enough new supply on the current development horizon, especially in Asia, to keep pace with increasing demand.

China's demand growth continues to be dominated by methanol to olefins (MTO) applications, although there is also some new demand expected in traditional chemical applications like formaldehyde. Three major new Chinese MTO projects based on merchant methanol are commissioning or due to do so over the next few months, bringing 4.5 million t/a of additional methanol demand. Asia ex-China is otherwise the region that is seeing fastest demand growth, in India, southeast Asia and Japan, Korea and Taiwan. There is no new capacity planned here though, so more imports are in the forecast. Likewise European demand is slow but steady and there is no new investment in capacity, so Europe will also see more imports. Low gas prices in North America continue to encourage new capacity developments, and the US will be an increasing exporter. There is also new capacity due in Trinidad at the end of 2019.

Mark forecast an extra 22 million t/a of methanol demand to 2028, with firm supply only accounting for 9-9.5 million t/a and a similar figure for possible/potential new supply. With the prospect of methanol supply being tighter going forward, Chinese coal prices could prove decisive in terms of availability of supply, while MTO demand, as the 'marginal consumer' of methanol, depends on oil prices – higher oil prices will see higher MTO demand for methanol.

Safety

With methanol increasingly in use as a fuel, it is more frequently finding its way to gas stations and fuel distributors who may not have much experience with its use and hazards. Greg Dolan of the Methanol Institute reviewed the Institute's recent safe handling manual, developed by Alliance Consulting and SP Technical Research Institute, intended for those involved in the distribution and use of methanol, and available from the MI website with accompanying video, newsletters, technical bulletins etc.

On the process safety side, meanwhile, Alan D'Ambrogio of ABB Consulting described what he called the 'watermelon effect' – the concept that your process safety performance indicators may be showing green lights that hide a red for danger situation building beneath and create a false impression that risks are under control when they are not. The solution, he said, was to question the metrics and whether they were measuring what you think they are measuring, and whether apparently minor hazards are being recorded properly.

Two speakers from Industrial Plant Services Ltd detailed the lessons learned from several reformer fires at the M5000 plant in Trinidad, which turned out to be caused by defective welds.

Two papers, by Stephen Shapcott of JM and Phillip Prueter of Equity Engineering, also discussed the issue of high temperature hydrogen attack, and ways of mitigating it – this will be the subject of an article in the next issue of *Nitrogen+Syngas*.

Operator experiences

As usual, several methanol manufacturers spoke on their own operating experiences. Methanex's Justin Bader described work conducted at the company's 1980s vintage Kitimat methanol plant to modify the back-up syngas turbine to allow the plant to continue operating while waiting for a replacement main syngas rotor following a failure in service.

The International Methanol Company (IMC) in Saudi Arabia have completed an efficiency enhancement project in conjunction with Worley, who had designed the steam reformer. A new pre-reformer and autothermal reformer were added courtesy of JM, as well as a fired heater, and a once through reactor to generate the additional methanol.

Methanex has relocated two of its methanol plants from Punta Arenas, at the southern tip of Chile, to Geismar, Louisiana. Clay Currier of Methanex took delegates through that procedure, which involved cutting the plants up into modular sections which were then loaded onto barges, and the barges in turn loaded wholeale onto a semi-submersible heavy transport for the several thousand kilometre journey around the coasts of South America and across the Caribbean to Louisiana. A new 'heavy haul' road had to be built to allow the plant sections to be brought to the site.

Finally, Mark McKenna of JM looked at the installation of a JM autothermal reformer at a 3,300 t/d methanol plant and the effects upon the site's overall equipment effectiveness (OEE) – in effect its on-stream availability at maximum permissible operating rate and required product quality, excluding downtime for external factors such as gas restriction. While 85% is a good benchmark figure for OEE, the new reformer brought this up to 99% for the plant in question.

Methanol technology

JM ran through the gamut of its methanol and catalyst technologies, including a look at the maximum potential size for a methanol plant. Although the 7,000 t/d Kaveh methanol plant in Iran, just beginning commercial operations, is the largest plant currently built, JM believes that 10,000 t/d is the largest current single stream capacity that can be achieved – beyond that multiple streams of various major equipment items would be required.

Daniel Sheldon of JM next went through the various methanol flowsheet options available, preceded by Simon Early's discussion of the "mathematics of syngas", or rather, its stoichiometry, which indicates the maximum methanol make comes from a hydrogen to carbon ration of 2.

Via a collaboration with Eastman, JM can also now offer mono-ethylene glycol (MEG) as an option for methanol plants. MEG consumption is currently 30 million t/a, and this is growing by 5% per year. JM has now licensed the new technology to a Chinese customer who are building a 1 million t/a MEG plant using coal-derived syngas.

Meanwhile, as the chemical industry tries to move towards more sustainable production, it is having to consider alternative feedstocks. Peter Ellis using hydrogen derived from electrolysis using renewable electricity as a methanol feedstock, as well as other pathways, including co-electrolysis of water and carbon dioxide and direct catalytic reduction of CO_2 to CH_3OH.

JM's Andrew Coe looked at use of gasified waste as a feedstock for methanol production. Gasification generates a low hydrogen syngas, so there is usually a shift reaction to convert some of the CO to CO_2 to get the correct ratio, but other options include using a gas-heated reformer or autothermal reformer to generate extra hydrogen. Via a collaboration with BP, JM have also been working on a Fischer-Tropsch synthesis to convert syngas to synthetic diesel.

Pablo Cardin of Schmidt and Clemens presented some of the latest developments for stream reformer outlet manifold systems, which operate at severe conditions up to the metallurgical limits of the material. Creep failure is the main failure mode for these components, and Pablo described Schmidt and Clemens' new Centralloy G4852 Micro R, with higher carbide content for better creep resistance.

Can your radiant shield boiler run dry, asked Brendon Miller of Jambec Consulting? The answer, according to modelling work undertaken to determine the response of a steam reformer in the aftermath of a trip caused by loss of boiler feed water supply, is apparently no, assuming that a steam drum hold up of 15 minutes is available.

New catalyst

JM also presented a new methanol synthesis catalyst; *KATALCO 51-102*. Methanol catalysts undergo significant deactivation (up to 60-80%) of their activity over the course of their lives due to thermal sintering. This deactivation is caused by copper atoms in the catalyst migrating at high temperatures and agglomerating, reducing the surface area of copper available, or sometimes poisoning by chlorides. The new catalyst has smaller copper nanoparticles and improved sintering resistance due to the copper being stabilised via a process still at the patent stage. While the catalyst has no real change in physical properties or selectivity, it does have higher activity, which increases as the catalyst ages, according to accelerated ageing tests. The catalyst now has its first industrial reference, at the G2X Energy methanol plant at Pampa in Texas, where it has been in service for three months.

JM has also constructed a methanol side stream test unit at the G2X Pampa Fuels plant which it uses to test different catalyst formulations, including the *Catacel* foil-based catalyst series, as described by Layne Clark of Proman, owners of G2X. However, during a turnaround in December 2018, JM was able to install *Catacel SSR* in the main steam methane reformer, as well as *KATALCO 51-102* in the 185 t/d methanol synthesis unit. Layne presented operating data from the past few months of the service of the *Catacel* catalyst which showed a lower methane slip and pressure drop, as well as the higher methanol make from the *51-102*.

Syngas project listing 2019

The Petronas methanol facility, Labuan, Malaysia.

A round-up of current and proposed projects involving non-nitrogen synthesis gas derivatives, including methanol, hydrogen, synthetic/substitute natural gas (SNG) and gas- and coal to liquids (GTL/CTL) plants.

Contractor	Licensor	Company	Location	Product	mt/d	Status	Start-up date
CANADA							
n.a.	n.a.	Nauticol	Grande Prairie, AB	Methanol	3,000	P	2023
CHINA							
n.a.	JM (DAVY™)	Shenhua Yulin Energy	Yulin, Shaanxi	Methanol	6,120	UC	2020
n.a.	JM (DAVY™)	Shaanxi Yanchang	Shaanxi	Methanol	5,760	UC	2020
n.a.	JM (DAVY™)	Suxin Energy Hefeng	Tacheng, Xinjiang	SNG	2 bcm/a	C	2019
n.a.	JM (DAVY™)	Lianhe Energy	Baotou, Mongolia	SNG	0.5 bcm/a	UC	2019
n.a.	JM (DAVY™)	Qinghai Provincial Mining	Qinghai	Methanol	5,800	C	2018
Casale	Casale	Shandong Jinmei	Zhangqiu, Shandong	Methanol	2,000	UC	2019
n.a.	Eastman/JM (DAVY™)	Inner Mongolia Jiutai	Togtoh, Mongolia	MEG	3,000	BE	2021
INDIA							
Engineers India Ltd	Haldor Topose	Assam Petrochemicals	Namrup	Methanol	525	UC	2019
n.a.	TechnipFMC	HPCL	Vishakhpatnam	Hydrogen	2 x 340	UC	2020
INDONESIA							
n.a.	n.a.	Petronas	Bintulu, Sarawak	Methanol	n.a.	FS	n.a.
n.a.	Air Liquide	Pertamina	Balikpapan	Hydrogen	260	UC	2021

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

PHOTO: HKHTT HJ/SHUTTERSTOCK.COM

Contractor	Licensor	Company	Location	Product	mt/d	Status	Start-up date
IRAN							
Namvaran	Haldor Topsoe	Marjan Petrochemical	Marjan	Methanol	5,000	C	2018
PIDEC	Casale	Kaveh Methanol	Dayyer	Methanol	7,000	C	2018
Namvaran	Haldor Topsoe	Badr-e-Shargh Pet Co	Chabahar	Methanol	5,000	BE	n.a.
PIDEC	Casale	Apadana Methanol	Assaluyeh	Methanol	5,000	UC	On hold
n.a.	Casale	Bushehr Pet Co	Assaluyeh	Methanol	5,000	UC	On hold
n.a.	Casale	Fateh Sanat Kimia	Dayyer	Methanol	5,000	UC	On hold
MALAYSIA							
Samsung	Air Liquide	Sarawak Petchem	Bintulu	Methanol	5,000	DE	2023
NETHERLANDS							
n.a.	Air Liquide	W2C Rotterdam	Botlek	Methanol	665	DE	2021
NIGERIA							
n.a.	Haldor Topsoe	Brass Fert & Petchem	Brass Island	Methanol	5,000	DE	n.a.
OMAN							
n.a.	Shell	TBA	Duqm	GTL	6,000	P	n.a.
RUSSIA							
n.a.	Haldor Topsoe	Shchekinoazot	Shchekino	Methanol	1,350	C	2019
Hyundai	TEC	Nakhodka Fertilizer	Nakhodka	Methanol	5,000	DE	2022
MHI	Haldor Topsoe	Baltic Gas Chemical	Ust-Luga	Methanol	5,000	CA	2023
n.a.	Haldor Topsoe	Nizhnekamskneftekhim	Nizhnekamsk	Methanol	1,500	CA	n.a.
TRINIDAD AND TOBAGO							
MHI	MGC	Caribbean Gas Chemical	La Brea	Methanol	3,000	UC	2019
MHI	MGC	Caribbean Gas Chemical	La Brea	DME	300	UC	2019
n.a.	Sasol	NiQuan Energy	Pointe a Pierre	GTL	250	UC	2021
TURKMENISTAN							
Hyundai/LG/Itochu	Haldor Topsoe	Turkmen GTL	Ashgabat	GTL	2,200	C	2019
Hyundai	Haldor Topsoe	Turkmenbashi Refinery	Turkmenbashi	Hydrogen	100	UC	2019
UNITED STATES							
Proman	JM (DAVY™)	Big Lake Fuels	Lake Charles, LA	Methanol/MTG	4,200	C	2019
n.a.	Relocated plant	US Methanol	Charleston, WV	Methanol	480	UC	2019
Jereh Oil Gas Eng	Primus Green Energy	Primus Green Energy	Proctor, WV	Methanol	160	UC	2020
Fluor	n.a.	Yuhuang Chem Ind	Lake Charles, LA	Methanol	4,800	UC	2020
n.a.	Linde	Delaware City Refinery	Delaware City, DE	Hydrogen	n.a.	UC	2020
Linde	Linde	Praxair (Linde)	St James Parish, LA	Hydrogen	425	DE	2021
n.a.	Air Liquide	Air Liquide	California	Hydrogen	30	DE	2022
Fluor	JM (DAVY™)	South Louisiana Methanol	St James Parish, LA	Methanol	5,000	DE	2023
JH Kelly	JM (DAVY™)	Northwest Innovation	Kalama, WA	Methanol	5,450	DE	2023
n.a.	JM (DAVY™)	Northwest Innovation	Clatskanie, OR	Methanol	2 x 5,000	DE	2023
n.a.	KBR	Methanex	Geismar, LA	Methanol	5,000	DE	2023
UZBEKISTAN							
Hyundai	Haldor Topsoe/Sasol	Oltin Yo'l GTL	Shurtan	GTL	5,000	UC	2020

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

THE IMPORTANCE OF A LEAK DETECTION SYSTEM IN UREA PLANTS

A STAMICARBON ADVANCE MONITOR™ CASE STUDY

To ensure safe operation of lined High Pressure equipment in urea plants, a reliable Leak Detection Monitoring System is essential.

A Leak Detection System continuously monitors the lining of the High Pressure equipment for leaks and, should a leak be detected, immediately shuts down the plant in a controlled manner in order to prevent serious damage to the equipment and the environment.

LEAK DETECTION SYSTEM BENEFITS:

- It continuously monitors the tightness of the lining and activates an alarm when a leak is detected
- The response time of the system is less than 60 minutes
- The estimated size of the leak can be calculated and the location can be identified
- Fail safe design of the complete system that handles malfunctions, such as blocked or leaking lines
- It accurately detects and measures ammonia in the ppm range
- It enables you to simultaneously monitor multiple High Pressure Equipments

Contact us for more information about our Leak Detection Monitoring System:
communication@stamicarbon.com

THE CASE STUDY

THE SITUATION:

A visible leak was detected in the spherical dome part of the HP Scrubber (lined with 316L UG stainless steel) of a urea plant. The plant was shut down immediately in order to attend the leak. Upon opening of the HP Scrubber sphere, it became clear that severe corrosion had occurred on the liners, which resulted in many visible cracks. Unfortunately, these cracks resulted in leaks which were not noticed. Therefore corrosion of the carbon-steel pressure part remained undetected.

This incident can be classified as a near miss.
Fortunately, the corrosion of the pressure retaining part resulted in a so-called “leak-before-break” scenario (LBB), allowing a timely shut down of the plant to avoid catastrophic failure.

THE ROOT CAUSE:

The leakage in the HP Stripper’s 316L UG liner was due to intergranular corrosion cracking, initiated at the process medium side of the liner. Ammonium-carbamate entering the space behind the liner started to corrode the carbon-steel.

This resulted in localized wall thinning of the carbon-steel pressure shell.

THE REPAIR:

The repair of the Scrubber sphere required 2 phases:

Phase 1: Removing the damaged liner and repair the carbon-steel pressure shell

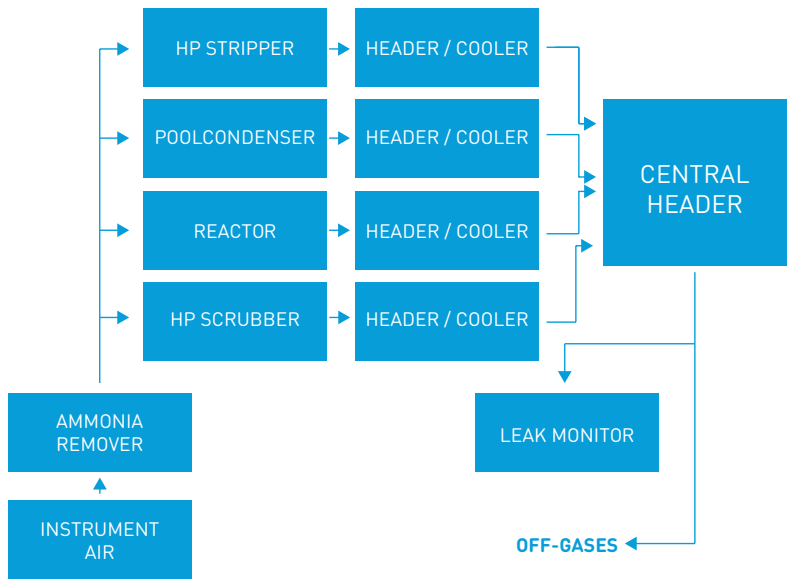
Phase 2: Installation of the new liner segments

Both phases were executed successfully.

THE CONCLUSION:

The severe corrosion of the pressure bearing part of the sphere is due to the fact that the liner leakage preceding this corrosion was not noticed. This demonstrates the importance of a reliable and robust leak detection system.

Stamicarbon recommends to implement a superior leak detection system, which is based on continuous forced air flow, fed to an ammonia analyzer (so-called pressurize system), which can be connected to the DCS system, as demonstrated in the diagram below:



A star is born

PHOTO: JUUL THIELEN FILMS

A new HP stripper featuring Safurex® Star material arrives at OCI Nitrogen's Sittard-Geleen urea plant in the Netherlands.*

Safurex® Star* goes operational to improve passive corrosion resistance, help reduce energy consumption and environmental footprint and increase the lifetime and throughput of urea plants.

Safurex® materials have been used for more than 20 years in the synthesis section of urea plants and have become the standard for urea plants using technology by Stamicarbon, the innovation and license company of Maire Tecnimont Group. Thanks to its superior corrosion resistance, and improved processing, Safurex® outperforms other viable stainless steels for high-pressure applications. To date, more than 400 pieces of equipment have been built using Safurex®.

Developed by Stamicarbon, in partnership with Sandvik Materials Technology, this super duplex stainless steel was first created to minimise known forms of corrosion that occur in a urea plant.

With over 70 years of experience of designing urea plants, Stamicarbon understands the critical issues in the urea process and the severe conditions to which equipment is exposed. Even though almost 90% of all corrosion issues have been eliminated, Stamicarbon is continuously improving its technology. Realising that various applications and parts of equipment are exposed to challenging conditions, each requiring different but specific material characteristics to ensure optimal performance, Stamicarbon has recently extended its material solutions to include new Safurex® grades. The new grades further improve the material's resistance to corrosive conditions and challenges that affect the high-pressure (HP) stripper.

On March 25, 2019, a HP stripper featuring the new Safurex® Star* material, embarked on its long journey from Austria to the Netherlands.

The 97.5 tonne piece of equipment was transported more than 1,000 kilometres over three days from the equipment manufacturer Schoeller-Bleckmann Nitec GmbH (SBN) to arrive at OCI Nitrogen's Sittard-Geleen urea plant one week ahead of schedule.

Designed by Stamicarbon, the new stripper is due to be installed mid-2019, replacing the existing equipment that has been in operation since 1998.

"They are designed with a lifetime of 20 years, so we have reached the end of the lifetime for the current stripper," explained Ruud Swarts, Manager Technology and Energy at OCI Nitrogen. "This replacement is a crucial part of our plant improvement strategy to reduce energy consumption and optimise operations."

OCI Nitrogen was the first to order a stripper with Safurex® Star* and Safurex® Degree° materials, while another order with an express delivery time of just under nine months for a producer in the Middle East went into operation in May 2019. Stamicarbon confirmed more orders are currently in the pipeline.

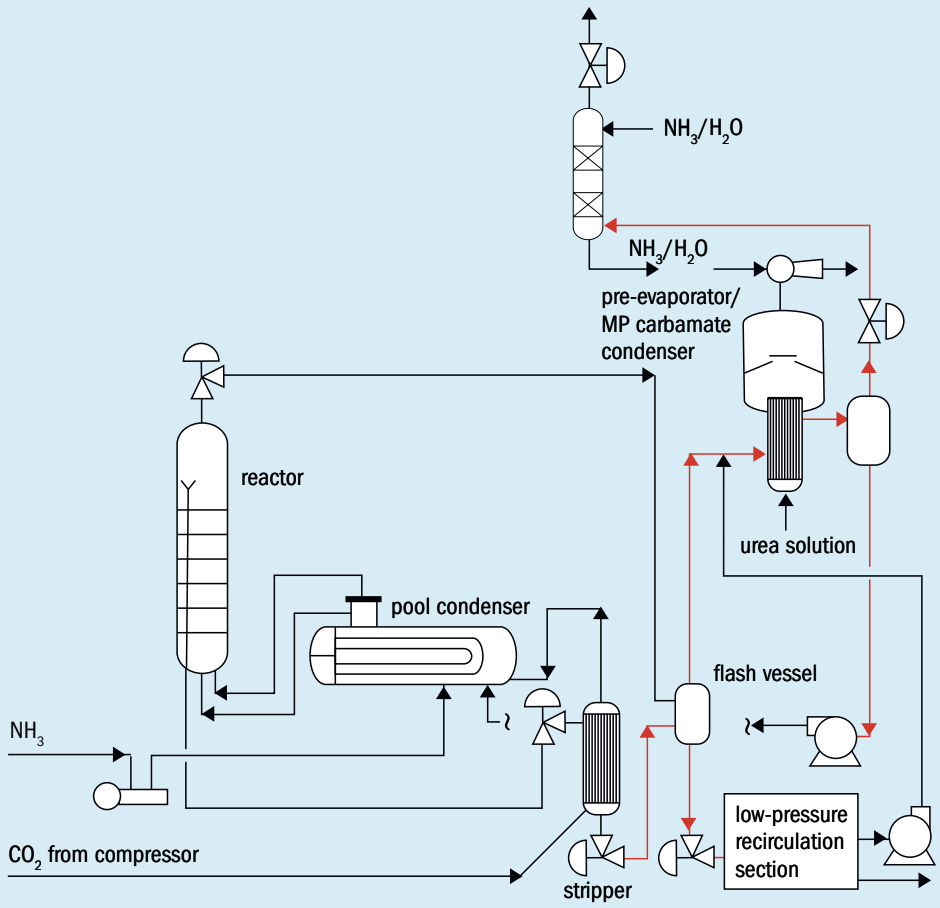
"These new grades of Safurex® make the equipment more durable, optimising performance and maximising lifespan," said Joey Dobrée, Stamicarbon's Product Portfolio Manager. "The new Safurex® grades build on the core advantages of the original material which, for example, have eliminated the risk of active corrosion and therefore contribute significantly to the safety of urea plants."

Safurex® Star* and Safurex® Degree° represent the latest innovations to come out of the successful partnership between Stamicarbon and Sandvik Materials Technology, a developer and producer of advanced stainless steels, special alloys, titanium and other high performance materials.

"We realised that different and specific material characteristics are needed to

Fig. 1: **Stamicarbon's flash design**

Source: Stamicarbon



ensure optimal performance," Mr Dobrée said. "For example, Stamicarbon's most advanced stripper combines all three grades of Safurex®. We've used Safurex® Star* for the heat exchanger tubes, Safurex® Degree° for the liquid dividers and the radar level measurement equipment, and the standard grade (Safurex® Infinity∞) for the remaining parts that are in contact with the ammonium carbamate environment, such as the liner and gas risers."

Upgrade versus status quo

OCI Nitrogen, a subsidiary of OCI N.V., opted to upgrade their stripper after intensively reviewing test results and discussing options with both Stamicarbon and SBN. Compared to existing Safurex® grades, Safurex® Star* is expected to extend stripper lifetime to 25 years.

"Plant capacity has been increased over the past 20 years. We decided we wanted to upgrade our stripper so we can continue improving our plant for the next 20 years," said Mr Swarts, who is OCI Nitrogen's project manager for the new stripper. "For Safurex® Star*, the test results looked very promising, so we decided to upgrade, rather than replace one-to-one.

"Going for Safurex® allows us to lower oxygen concentration. We do not have the risk of active corrosion. With this new grade, we hope that it will be more resistant to passive corrosion than the previous material. In turn, we hope that less passive corrosion will extend the lifetime of the new stripper."

Energy reduction with an attractive return

Stamicarbon's revamp solutions offer not only a substantial reduction in energy costs but also higher capacity.

"Traditionally, plant owners have associated environmental improvements with a low or even negative return on investment. Our revamp concept using Safurex® Star* in combination with flash design enables urea plants to reduce their environmental footprint, while having an attractive payback period," Mr Dobrée said.

Fig. 1 shows Stamicarbon's flash design.

Increased capacity

"Aged HP strippers have an increased internal tube diameter due to corrosion of the tubes, so they can handle more liquid

What is Safurex® Star*?

Safurex® Star* is a special super duplex steel designed for application in the most demanding equipment (such as the HP stripper) in the CO_2 and thermal stripping process. It is designed especially for the heat exchanger tubes in the HP stripper for all types of urea processes based on thermal or CO_2 stripping.

What is Safurex® Degree°?

Safurex® Degree° is a super duplex steel fabricated via the hot isostatic pressing (HIP) method introduced by Sandvik and Stamicarbon in 2012. This results in an isotropic and fine-grained microstructure, which enhances the mechanical properties at low temperatures (-35°C) and also improves corrosion resistance, especially with respect to cross cut end attack. It is used for HP stripper ferrules.

What is Safurex® Infinity∞?

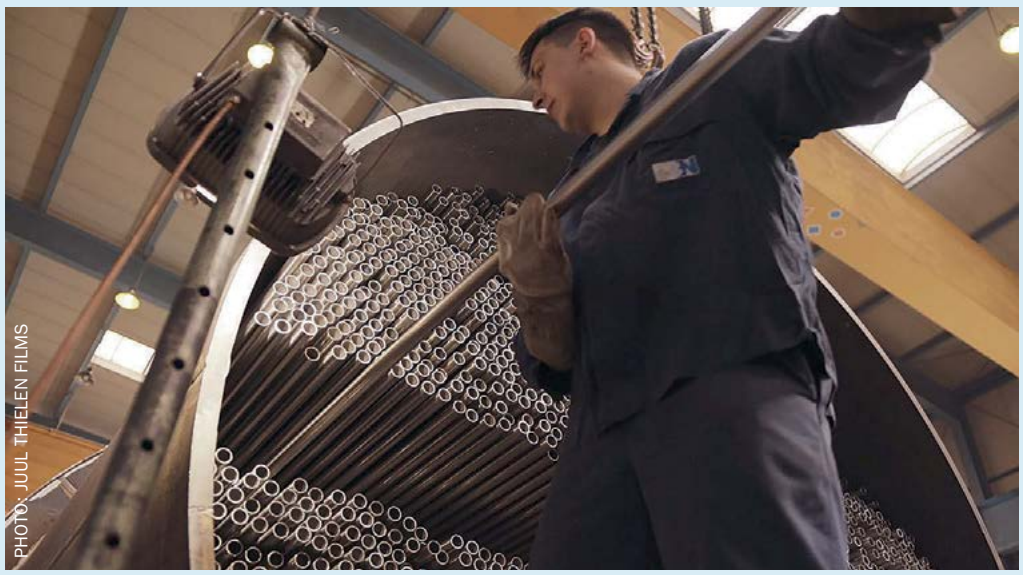
Safurex® Infinity∞ is the original grade of Safurex®, first introduced by Stamicarbon and Sandvik more than 20 years ago. It is a super duplex stainless steel that minimises known active forms of corrosion that occur in a urea plant, thanks to its superior corrosion resistance and improved processing. This material is used in all wetted parts of the high pressure urea synthesis section, such as (but not limited to): pool condensers and pool reactors, urea reactors, HP strippers, HP scrubbers, HP carbamate consensers and HP piping and accessories. For high-pressure applications, Safurex® outperforms any other viable stainless steel.

In brief, the Safurex® family of materials offer the following benefits:

- independency of passivation air;
- improved mechanical properties;
- resistance to chloride stress corrosion cracking;
- excellent weldability;
- no active corrosion.

First Safurex® Star* applications

Welding of the HP stripper at SBN's manufacturing site in Ternitz, Austria.



Installation of the new Safurex® Star stripper tubes.*

OCI Nitrogen's HP stripper en route from Austria to the Netherlands.

Stefan Huber, Project Manager at SBN, a global leading manufacturer of high pressure equipment for the fertilizer industry, said the company was proud to be the first manufacturer to deliver superior Safurex® Star* equipment.

"We feel honoured to be chosen to produce equipment with this demanding material grade and appreciate the trust put in SBN and our craftsmanship," Mr Huber said. "OCI Nitrogen had high quality standards, and we were very happy to be able to satisfy them."

Mr Huber said the project had progressed smoothly and on schedule, with excellent communication and cooperation between all parties. He also recalled the smooth welding qualification process prior to the welding of the HP stripper's tubesheet.

"A mock-up welding test is done for every project, and even though we were working with a new material, we were happy to pass this welding qualification within the first try. This is thanks to our highly-skilled welders who developed the welding program in advance and did their tests internally to guarantee a smooth qualification process. When welding new materials, we often have to try different parameters, so this went very smoothly, even on the first try."

SBN has now manufactured and delivered two HP strippers featuring Safurex® Star*; one in the Netherlands and another express delivery, in a record time of less than nine months, to a customer in the Middle East.

"I think that is one of our strengths and why we are often the preferred supplier, because we meet demanding lead times with the highest quality possible," he said.

The longstanding relationship between SBN, Stamicarbon and Sandvik is focused on continuous improvement. The best example for this fruitful partnership is now the second generation of Safurex®. "We produced the first original Safurex® equipment, developed welding techniques, performed testing and regularly shared our feedback. It's great to see this history being continued with the new material grade. It will provide a lot of benefits to clients all over the world, especially for use in HP strippers," Mr Huber said. ■

New Safurex® HP stripper ready for shipment at SBN, Austria.

load at constant liquid film thickness. This allows higher production without flooding issues," explained Robert Rozek, Stamicarbon Senior Mechanical Engineer.

"Once the HP stripper is replaced, the original diameter of the stripper tubes results in loss of internal tube circumference and thus lower liquid load at constant liquid film thickness. The immediate consequence is a capacity loss of around 6% compared to the performance of the aged HP stripper at the moment it is replaced. This results in direct loss of income for the plant owner."

Using Safurex® Star* resolves this issue and instead increases capacity. Stamicarbon's engineers are able to maintain the philosophy of a "one-on-one" replacement, while substantially increasing the capacity of the HP stripper within these restrictions.

"The use of a Safurex® Star* HP stripper avoids capacity loss as the liquid load can be increased to not only compensate this negative effect but even increase capacity beyond that of existing designs," Mr Rozek said. "This is made possible by the installation of more tubes with a thinner wall thickness in an optimised shell configuration."

In addition, use of Safurex® Star* in the HP stripper enables the reduction of oxygen content within the urea synthesis section (when the materials of the existing HP equipment are suitable for low oxygen operation). The low oxygen operation of the synthesis results in a higher urea conversion or synthesis load, enabling an increase in production capacity.

Lower weight

The weight of the new Safurex® Star* HP stripper is lower compared to a new original HP stripper with austenitic stainless steel tubes, because of the superior material properties. Therefore, no structural modifications and fortifications are required, meaning the HP stripper exchange has the characteristics of a "one-on-one" replacement, without the need to modify HP piping.

Saving on steam

The HP stripper is operated at lower stripping efficiency resulting in lower HP steam demand of the stripper and corresponding lower LP steam production in the HP pool condenser. The overall energy demand of the plant is balanced by applying Stamicarbon's flash design in such a way that LP steam export is almost zero. This is realised by the heat generated by the off-gases from the urea synthesis, and the flashed vapours from the urea solution from the HP stripper are re-used in a pre-evaporator to optimise the energy balance of the plant. The savings related to the reduced need of import of 25 bara HP steam generates an advantage of around 100-150 kg of HP steam per ton of urea, which translates to a saving of over $3 million per year for a world-scale urea plant.

Pioneering with Safurex®

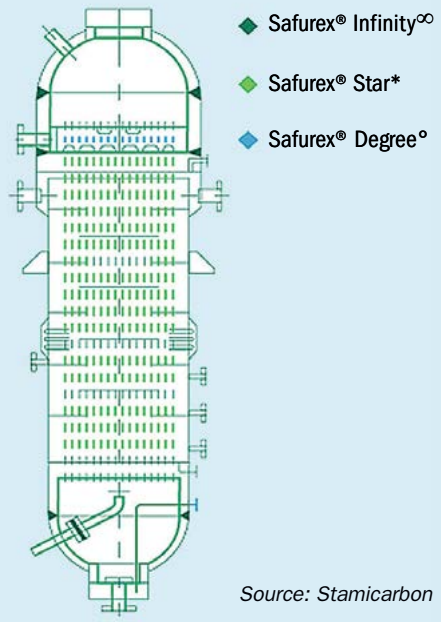
It is not the first time that OCI Nitrogen has pioneered Safurex®. Their existing stripper is the first to feature the first generation tubes made with the original Safurex® material.

"The cooperation with Stamicarbon and SBN was very pleasant. We had a lot of discussion. All documents were there, the quality was very good and if there were any problems they were resolved quickly," Mr Swarts said.

"We don't like to be an experimental plant. If the test results were not that clear, we would not have chosen Safurex® Star*, we would have opted for the standard material. It's important for us to have a piece of equipment that will last another 20 years, not one that needs to be replaced in ten." ■

Stamicarbon's Safurex® HP stripper

Stamicarbon's Safurex® HP stripper is a high pressure carbon steel vessel with a special alloy protection. It is a falling film heat exchanger with a liquid distributing system. Urea solution from the reactor is sent to the HP stripper. Here the concentration of urea is increased by decomposing carbamate from the urea solution into NH_3 and CO_2. This is done by contacting the urea solution, flowing through the tubes, with CO_2 counter currently and supplying high pressure steam on the outside of the tubes. The stripped urea solution is sent to the downstream sections of the plant. The off-gas of the decomposed carbamate is recycled back to the synthesis. ■



Source: Stamicarbon

Ammonia converter revamping

Upgrading the design of the ammonia converter and its internals can bring significant benefits including better use of catalyst volume for increased capacity, improved gas distribution, and reduced energy consumption.

The focal point of an ammonia plant is the synthesis loop, with the ammonia converter at its core. The ammonia converter vessel contains a cartridge for catalyst beds, heat exchangers and gas distribution pathways. Its internal design is very complex and is influenced by requirements such as assembling the internals inside the pressure vessel, inspection requirements, loading and unloading the catalyst.

High per-pass conversion means lower circulation and lower operating pressure. Both factors have a positive effect on the energy efficiency of the plant, because consumption of both the synthesis gas compressor and the circulator will be lower. As technology and materials have improved, it has become possible to make fuller and more efficient use of the converter volume. Consequently, revamping the synthesis converter of an existing plant to the newest technology can be of huge benefit on account of its positive effect on overall plant efficiency.

In recent decades, various licensors have provided technology for the ammonia synthesis loop, each with distinctive features: operating pressure, catalyst temperature control, heat removal, levels of inerts and loop layout. These differences are reflected in the design of the ammonia converter, in respect of not only the internals but also the pressure shell[1].

The size of the opening on the top of the vessel obviously influences the strategy for installing the new internals.

The positions of the main inlet and outlet nozzles influence the overall gas flow path. In addition, pressure vessels have a number of other nozzles for temperature control and measurement. The number, position and size of the available nozzles determines the layout of the converter internals, in terms of the number of catalyst beds and the way in which the reaction heat is removed.

The size of the pressure vessel defines the volume available for installation of new internals and catalyst, but the shape may heavily influence which options are technically feasible. Designing internals for an odd-shaped converter and mounting them requires detailed planning to ensure that the most efficient use is made of space and installation time. A significant increase in ammonia production is obtained if the volume of the ammonia converter is utilised more efficiently.

tkIS' improved ammonia converter design

Starting from its well-known and proven design, thyssenkrupp Industrial Solutions (tkIS) has developed a set of improvements allowing more catalyst to be installed in a given volume and to better utilise the catalyst volume.

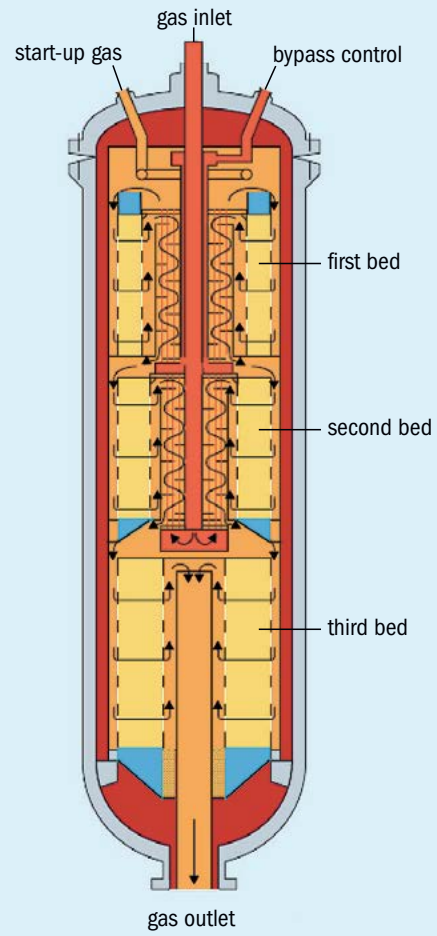
This evolutionary design[2] is well suited as a retrofit in an existing plant, enabling higher production just by replacement of the converter cartridge without changes to the costly pressure vessel. The new design can also be applied to new-build plants.

For many years the ammonia converter design with radial flow through the catalyst beds and heat exchange between the beds has been state-of-the-art. Reactors exist with one, two or three catalyst beds.

The reactor is designed in such a way that the catalyst (yellow area in Fig. 1) and the internal heat exchangers are not directly installed in the pressure vessel (grey area in Fig. 1). Instead, a cartridge holding them is inserted into the pressure vessel. This has the advantage that the cartridge can be easily replaced if it is damaged e.g. by nitriding caused by the gas atmosphere.

The pressure vessel is made from low-alloy material and designed for the full process pressure. The cartridge in contrast is designed for the actual gas temperature, but only for the differential pressure between the inlet and outlet streams plus a safety margin. It is usually made from stainless steel due to its higher resistance against creep and nitriding.

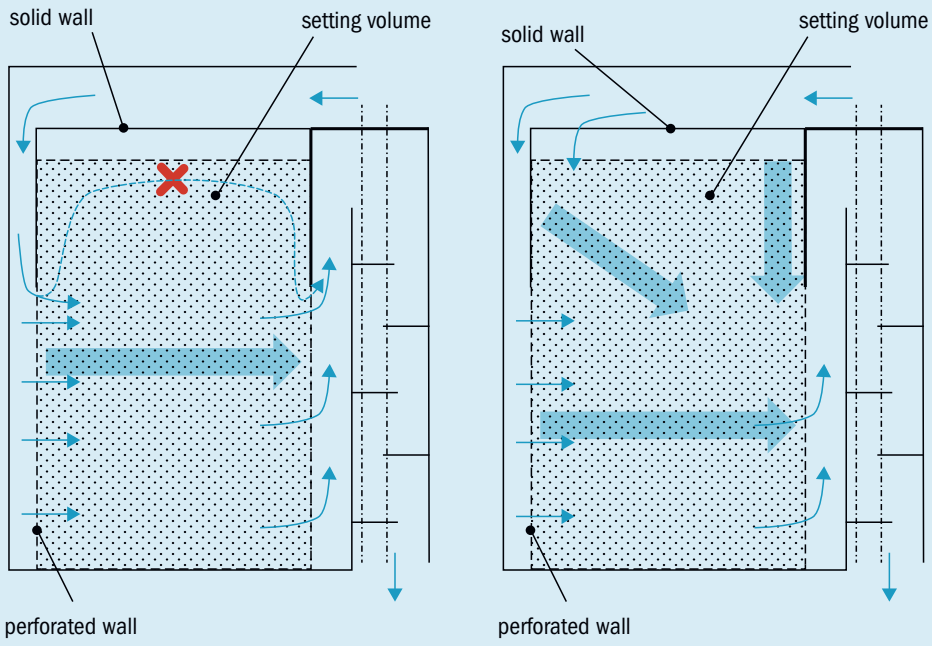
Fig. 1: **Schematic drawing of tkIS ammonia converter with three radial catalyst beds**



Conventional design and optimised design (blue)

Source: tkIS

Fig. 2: **Improvement of catalyst bed inlet flow**

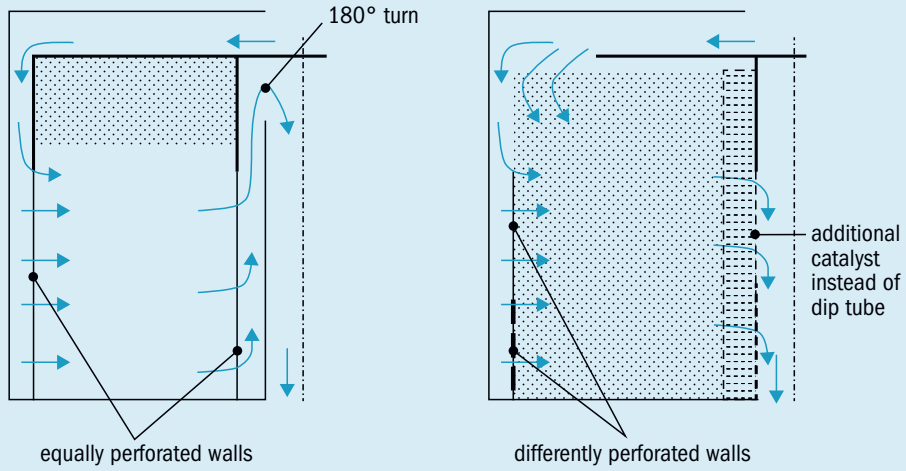


Conventional design

Optimised design with better utilisation of setting volume by different approach of gas flow

Source: tkIS

Fig. 3: **Elimination of the dip tube at the bottom catalyst bed**



Conventional design

Otimised design with higher catalyst volume and engineered wall performation

Source: tkIS

Due to the demanding operating conditions and the complicated internal design, the pressure vessel and the cartridge are quite expensive equipment items. It is therefore worthwhile to develop a more efficient design.

In Fig. 1 it can be seen that only a portion of the valuable high-pressure volume inside the vessel is used for its original purpose – the catalyst beds and inter-bed heat exchangers. The rest of the volume is not always used most efficiently and was the focus of tkIS' recent improvements to the ammonia converter design.

Better utilisation of the previously unused volume includes the use of the catalyst settling volume, elimination of the dip tube at the outlet of the last bed, and utilisation of the formerly unused vessel volume.

Use of catalyst settling volume

Temperature and pressure cycling during operation can lead to catalyst particles being crushed, which leads to a decrease in filling height. Therefore, the bed is usually designed with an allowance for settling (Fig. 2, left side). The main gas flow does not pass through the settling volume, which therefore barely contributes to ammonia formation.

To improve the utilisation of catalyst, the design of the bed inflow has been modified as shown in Fig. 2, right side. The perforation on the outer wall has been extended up to the very top of the bed and the outer part of the top cover is also now perforated. This allows the gas to enter the catalyst via the outer top edge. The flow also now passes through the settling volume, producing some additional ammonia there. If the filling height should get less over time, the design avoids any shortcuts and bypassing of the catalyst.

Elimination of dip tube at outlet of last bed

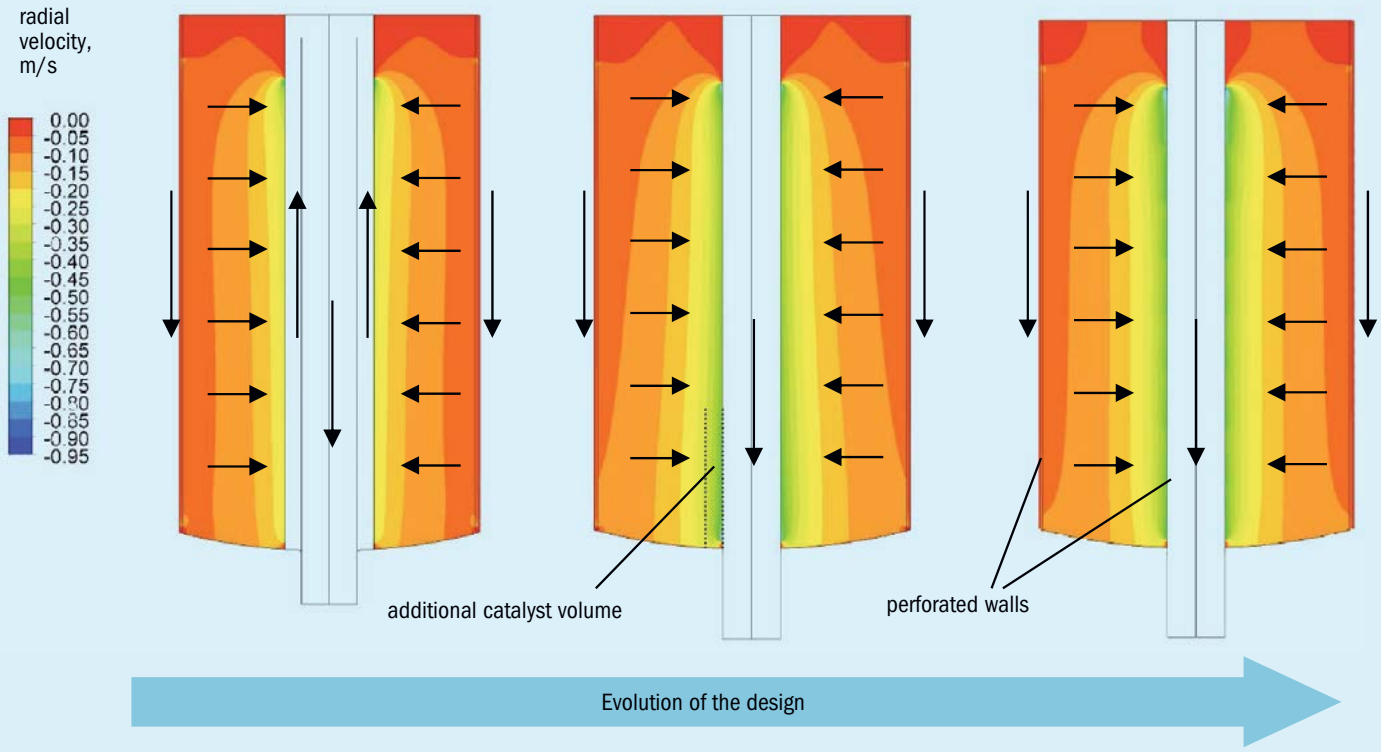
In the conventional design, as shown in Fig. 1, the flow follows a U-shaped pattern for all catalyst beds. Gas enters an annular gap from the top, passes horizontally through the catalyst bed, then moves upward again in the outlet annular gap.

Equal flow distribution is important because it ensures all gas molecules have the same residence time inside the catalyst, thus achieving the highest conversion. If a portion of the gas had shorter residence time, lower ammonia concentration would be achieved. This would not be counterbalanced by another portion with longer residence time, because its conversion would be limited by equilibrium.

This important equal flow distribution is ensured by the U-shaped flow arrangement. This is also confirmed by CFD simulation as shown in Fig. 4, left side. However, for the bottom bed (left side in Fig. 3) the upward flow at the outlet leads to longer flow path and extra space requirement.

It looks like a simple idea to remove the central tube and to extend the catalyst bed further inward to the former wall of the central tube, thus utilising the annular collector for catalyst instead. However, this alone would not work. The flow distribution across the bed would give a very uneven pattern with high flow in the bottom and low flow at the top of the bed, as shown in Fig. 4, centre.

Fig. 4: **CFD simulation for radial velocity of the gas through the bottom catalyst bed**



Source: tkIS

This happens because the gas flow in the annular spaces for inlet and outlet flow changes its velocity over the vessel height and thus its static and dynamic pressure vary differently on the outer and inner side.

To avoid maldistribution when no U-shaped flow is present, a catalyst basket has been developed with differing flow resistance across the bed height by providing holes in the wall with different size or different distance to each other. A large open fraction at the top drives more gas through the upper catalyst layers. The proper sizing of the holes is determined by CFD analysis. The right side of Fig. 4 shows the perfect results.

Utilisation of formerly unused vessel volume

The new cartridge design is conical at the bottom to house more catalyst, as shown in Fig. 1, right side, marked in blue.

In the conventional design, the three catalyst beds are firmly installed in the cartridge. Each heat exchanger is only installed after the catalyst bed below it has been filled. Gaps are needed between the beds for access during assembly and filling.

The new cartridge design minimises these free volumes by a modular design in which only the lower catalyst bed is fixed to the cartridge. After it has been filled with catalyst, the centre bed (together with the heat exchanger) is stacked on top of it and filled with catalyst. The same is then done with the top bed. The advantages are that filling is easier due to better accessibility by the free space above it but no big gap is needed when the next bed is stacked on top of it.

The new design is shown in Fig. 1 using the example of a three-bed converter but it can be equally applied to a two-bed converter.

Full-service package for replacing cartridge and catalyst

Replacing the cartridge and catalyst in an ammonia converter is a complex, non-routine and time-critical task during a plant shutdown. In order to support its customers, tkIS is offering as general contractor a full-service package for cartridge and catalyst replacement. One key feature of the full-service package is a newly developed catalyst loading method which has been developed and successfully applied by Johnson Matthey and tkIS and which allows for significantly shorter catalyst filling durations[3]. Together with the optimised cartridge design tkIS' full-service package ensures not only a safe cartridge and catalyst replacement under observance of a set time schedule but also a guarantee for higher ammonia production.

Capacity increase

Taking a 1,200 t/d ammonia plant with a three-bed cartridge as an example, the new design modifications can increase the catalyst volume by more than 20%, resulting in a capacity increase of 7.5%, assuming that the front end is able to provide the required amount of synthesis gas and the cooling train of the loop either has sufficient margin or is modified accordingly. The increased capacity originates from the higher catalyst volume only and is achieved with constant synthesis loop recycle gas flow, which means that the loop operating conditions are not changed much.

Of course, a much higher increase in production can be obtained if the loop recycle flow is also increased and/or higher activity catalyst such as KATALCO™ 74-1 is used. A lot of modifications would be necessary in the plant for such a capacity increase but the good news is that a new high pressure shell for a new converter (replacement, parallel or booster) plus the associated pipework would not be required.

Casale ammonia converter revamping

Casale is a world-leading technology provider for ammonia converter revamping with the flexibility, world leading technology and know-how to cope with different situations, including cartridge replacement in converter shells with full-bore or partial opening, in-situ retrofits of existing cartridges as well as completely new ammonia converters.

The following case history discusses the recent successful converter revamp in Abu Qir III which provided improved ammonia plant efficiency and reliability within a short shutdown period and with minimal impact on normal plant operation[4].

Revamping of Abu Qir III ammonia converter

Abu Qir plant III, originally licensed by Uhde, was commissioned in October 1998 and produces 1,200 t/d liquid ammonia and 1,750 t/d urea granules.

Ammonia plant III was equipped with its original three-bed radial-flow converter and the converter basket, internal heat exchangers and ammonia catalyst were approaching the end of their useful life. Instead of proceeding with an in-kind replacement, Abu Qir chose to revamp its ammonia converter in a turnaround in 2018, in order to maximise energy savings in the synthesis loop.

One idea to optimise project economics was to use some remaining catalyst from the previous charges available in Abu Qir's warehouse.

Abu Qir options for internals replacement were:

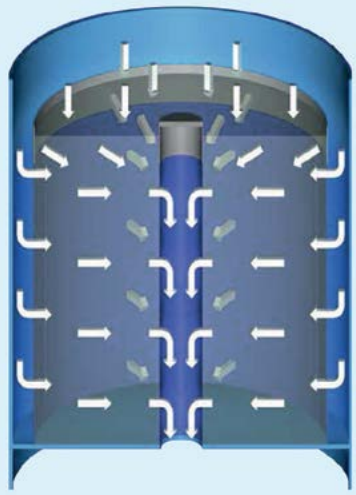
- replacement (similar design) utilising its catalyst;
- replacement (similar design) utilising new fresh catalyst;
- revamp ammonia converter basket (improved design) with internal resources optimisation.

The last option was considered to be the most economically attractive since it combined converter performance improvement, thus reducing operational costs, with re-use of existing resources.

After the project was assigned to Casale, the usual approach for converter revamping was applied:

- operating data analysis;
- synthesis loop, refrigeration section and ammonia converter process reconciliation;

Fig. 5: **Axial-radial flow pattern (full catalyst utilisation)**



Source: Casale

- ammonia converter new internals design;
- synthesis loop and refrigeration section simulation with new internals to calculate benefits.

In addition, Abu Qir's available catalyst was tested by Casale and the new catalyst vendor and was found to be in good condition and suitable for the converter revamping project. It was decided to use the catalyst in the second and third ammonia converter beds and to buy new pre-reduced catalyst for the first bed only.

Casale internals design philosophy

In order to maximise the catalyst installed volume, hence maximise ammonia conversion and synloop energy saving, Casale adopted the well-known revamping configuration: 3 catalytic beds with interchangers between the 1st and 2nd bed and between the 2nd and 3rd bed, coupled with the use of Casale patented axial-radial internals. With Casale new internals it was possible to increase the installed catalytic volume by about 30% compared to the previous design.

The higher efficiency of Casale internals together with the well-known Casale cold-wall design allows the converter to operate at a lower thermal level, thus improving its expected lifetime.

Independent control of each of the three beds temperatures was foreseen since it is essential to obtain optimum operation of the converter at all times, i.e. with new as well as aged catalyst and at different plant loads, for maximum energy saving and thus highest return on the converter retrofit investment.

The new converter internals feature:

- a fixed cylindrical cartridge, which separates the catalyst baskets from the pressure vessel wall, allowing the vessel wall to be kept cool by flushing it with the incoming gas;
- first and second axial-radial flow type removable catalyst baskets for a three-bed design;
- a third (bottom) fixed axial-radial catalyst basket;
- two internal heat exchangers.

The catalyst beds have two cylindrical walls, one external (near the cartridge wall) and one internal, to contain and support the catalyst mass providing mechanical strength and to provide uniform gas distribution throughout the whole bed volume in order to get the best catalyst performance.

Each of the three axial-radial baskets is designed with open top catalyst beds, which compared to conventional radial designs, has the following advantages:

- utilises efficiently the full volume of the catalytic beds, including the top layer (Fig. 5);
- easier mechanical construction, not requiring completely top sealed catalytic beds;
- easier catalyst loading and unloading;
- easy and controllable dense loading of the catalyst to obtain high and uniform bulk density.

To avoid any movement or spillage of the catalyst loaded in the top portion of the catalytic bed in upset conditions, proper means, such as slotted protection screens, are installed.

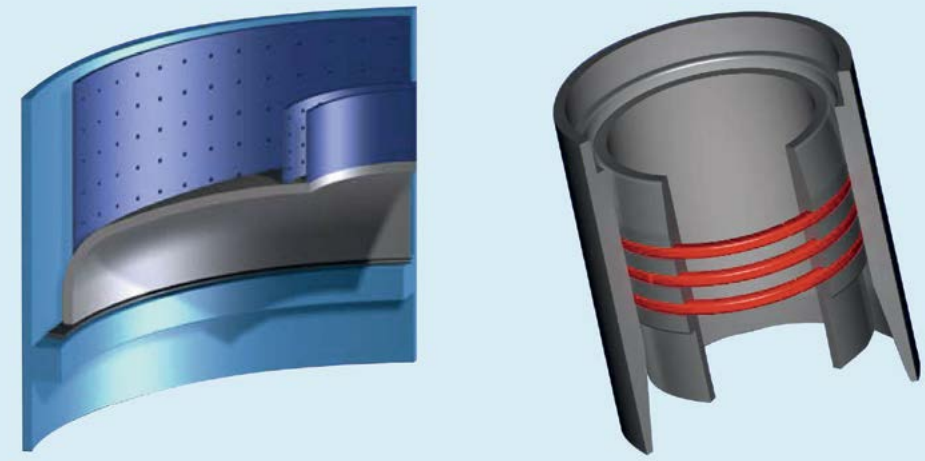
The axial-radial flow pattern in the catalyst results in an empty cylindrical core around the converter centreline, which is the ideal location for the interbed heat exchangers.

To save costly converter space, Casale adopts a special design that allows high heat transfer rates to be obtained with comparatively low pressure drop and eliminates vibration problems.

The bottoms of the removable baskets are inverted dished heads. Besides simplifying the sealing problems, this arrangement allows better utilisation of the converter volume (i.e. more catalyst can be packed in these baskets).

The different interconnected metal parts, which combined constitute the internals, reach very different steady state temperatures in an operating converter. To cope with different thermal expansions, Casale only uses bellows expansion joints where

Fig. 6: **Reverse disk bottom closure and elastic ring seal rings**



Source: Casale

Fig. 7: **Cartridge lift and installation inside converter shell**

PHOTOS: CASALE

Fig. 8: **Catalyst dense loading**

PHOTOS: CASALE

they are easily accessible for assembly and disassembly (i.e. at the reactor top).

For converter inner parts, since they are not easily accessible, Casale patented elastic seal rings are used (Fig. 6); in this way it is possible to reduce internal leakages with smaller axial dimensions and shorter length.

Casale internals installation

The pressure vessel was unbolted to unload catalyst and remove the existing cartridge. The pressure vessel was then inspected, the stud bolts and gaskets seating surface were protected.

A new cartridge was then lifted and installed inside the pressure vessel (Fig. 7).

The expansion joint assembly on the converter outlet nozzle was installed and welded up to the cartridge bottom pipe, then the cartridge top cover was removed.

After removal of the protection screen and lifting of the 1st bed basket, it was possible to unbolt and remove thermowell pipes. To ensure a proper reading during converter operation, water moisture and dirt must be prevented from infiltrating the inside of the thermowell pipes: special care is therefore taken to plug and seal the thermowell pipes openings.

Internal heat exchangers were already welded and in position inside the new cartridge; they are normally never removed during cartridge installation.

Using the same procedure as for the first bed, the second bed basket was removed and catalyst loading was started in the third bed.

Special attention must be given during catalyst loading to preserve catalyst activity and the integrity of the converter internals.

Oxidised catalyst is completely unreduced and does not present any risk of reactions with ambient air; conversely, pre-reduced catalyst is obtained by the complete reduction of oxidised catalyst and its following skin oxidation. Just 2% of such catalyst is oxidised.

Reduced catalyst can react with air even at ambient temperature; if such a reaction occurs, the temperature can easily rise since the oxidation reaction is exothermic, causing both catalyst and converter internals damage.

For these reasons, pre-reduced catalyst loading (converter first bed) must be performed under a nitrogen atmosphere.

Special nitrogen connections are used to flush the converter and a temporary cartridge closure cover and polyethylene sheets are used to cover all areas were catalyst is handled.

Fig. 9: **Cartridge top and expansion joints**

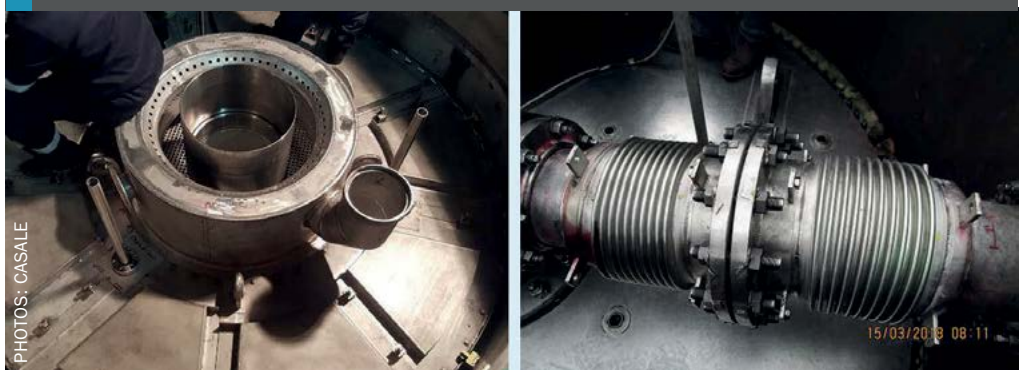


Table 1: **Comparison between operating conditions in base case and revamped case**

	Base case	Revamped case (expected)	
		SOR	EOR
Production across converter, t/d	1200	1,200	1,200
Installed catalyst volume, m^3	52.3	66.7	
Synloop pressure (at circulator discharge) bar g	188.3	167	170.5
Synloop pressure drop, bar	12.8	10.9	11.2
Inerts % at converter inlet (including NH_3), mol-%	15.1%	15.65%	15.56%
ΔNH_3 across converter, mol-%	12.1%	14.0%	13.7%
Purge flow, Nm^3/h	8,966	8,966	8,966
Converter inlet temperature, °C	269	254	259
Converter outlet temperature, °C	441	448	449
Circulation (converter inlet), Nm^3/h	624,367	550,225	560,886

Source: Casale

Table 2: **Guaranteed figures vs test run results**

	Guaranteed	Test run (July 2018)
Loop production, t/d	1,200	1,218
Converter outlet NH_3 concentration, % mol	16.9%	17.0%
Converter pressure drop (excluding external valves), bar	2.6	1.66
Specific Energy Saving from base Case, Gcal/t	0.033	0.123*
Maximum circulator discharge pressure, bar g	171	170.2**

** Better energy saving with respect to guaranteed depends also on a higher than expected efficiency of syngas and ammonia compressors. ** Operating pressure slightly higher than expected due to higher production and slightly higher inert content.* *Source: Casale*

Catalyst is always screened before loading: in fact it is normally sieved to remove any dust before loading in the drums, however some dust can form during handling and transportation.

Catalyst loading is performed by using a dense loader (Fig. 8).

The amount of catalyst loaded is recorded while regularly monitoring (every 1,250 mm) catalyst distribution and bulk density (loaded catalyst weight and height are required) to maximise loaded catalyst bulk density.

After the third bed catalyst loading was completed, a relevant top protection screen was re-installed together with second bed basket and gaskets.

Catalyst loading of the second and first bed proceeded as described for the third bed. Thermowell pipes and relevant stuffing boxes were also re-installed. During first bed loading, the bed temperature was carefully monitored to ensure that no oxidation was occurring.

The cartridge cover was then re-installed and insulation sleeves welded in the main inlet nozzle and start-up/bypass nozzle. Finally, central pipe assembly and expansion joints assemblies were installed, and the pressure vessel was boxed up (Fig. 9).

All welds were 100% checked by dye penetrant test to ensure maximum reliability of internals. Installation of the new converter internals proceeded smoothly and was completed in less than 20 days as foreseen, with no impact on plant scheduled shutdown time.

Synthesis loop start-up

After the catalyst loading activities were completed, the catalyst reduction process took place on March 2018, under the supervision of Abu Qir, Casale and the catalyst vendor.

Thanks to the teamwork between all the parties, catalyst reduction was carried out smoothly, minimising the start-up time to less than five days from start-up heater first burner light-up to reduction completion.

Revamp results

The higher installed catalytic volume in the revamped converter together with the higher efficiency of Casale internals has led to a reduced energy consumption. Ammonia conversion has been increased, reducing circulation and leading to benefits in syngas and ammonia compressors power consumption and, thanks to new converter internals, the synloop pressure drop has been reduced with benefits in syngas compressor power consumption.

Table 1 shows a comparison between the operating conditions of the base case and the expected synloop working conditions of the revamped case.

After start-up, ammonia converter expected results were confirmed by operating data; performances were found to be excellent, leading to higher energy saving than expected (Table 2).

Energy saving is calculated as the difference between the base case consumption and the revamped case. Energy consumption is calculated as the sum of specific energy consumption of syngas compressor and ammonia compressor minus produced steam specific energy.

Besides the energy savings achieved, the revamp of the ammonia converter, synthesis loop and the compressors (syngas and frigo) provided additional room for future capacity increase.

KBR ammonia converter replacement

The following case history describes a recent project in which an original KBR two-bed horizontal converter at the Nutrien Fort Saskatchewan Nitrogen Operations (Nutrien FNO) ammonia plant, was replaced with KBR's more efficient three-bed horizontal ammonia converter[5]. The main project requirements were:

- upgraded shell material of construction;
- minimum modifications on existing structure and support;
- minimum impact on existing synthesis loop; and
- minimum impact on the turndown time.

The new reactor will also provide additional capacity for future expansion.

Nutrien FNO, (formerly Agrium) located at Fort Saskatchewan, Alberta, Canada, operates a 1980s ammonia plant with a current capacity of around 1,300 t/d, based on KBR conventional ammonia process technology with a two-bed, inter-cooled ammonia converter in the ammonia synthesis loop.

In October 2015, Nutrien FNO decided to replace the ammonia converter due to the following concerns:

- The existing ammonia converter pressure shell had some previous repairs and small cracks, due to HTHA, had been found in previous inspections. The material of construction also needed to be upgraded to meet current standards.
- Nutrien FNO expected a major turnaround period within three years to replace catalysts in the major reactors in the front-end of the ammonia plant;
- Nutrien FNO wanted to debottleneck the operation and increase the ammonia production in the near future.

After contacting KBR for a feasibility study on ammonia converter replacement, Nutrien FNO decided in 2016 to go ahead and replace the existing ammonia converter and basket with KBR's proprietary advanced three-bed, two-interchanger design.

Planning

The site logistical activities of the ammonia converter replacement project had to be well planned, thoroughly engineered, and executed smoothly to maintain the turnaround schedule of 39 days.

The existing ammonia converter plot space area is very tight and crowded. After evaluating the option of replacing the existing ammonia converter with either a vertical or horizontal one, Nutrien FNO determined that staying with a horizontal design would better suit the project objectives.

Replacing the existing converter with a horizontal one has the following advantages:

- maximum reuse of the existing inlet and outlet piping around the ammonia converter;
- reuse of the existing support saddles for the new converter;
- no new structure is required for the support of the new converter and the existing rails can be used for the removal of the existing ammonia converter and the installation of the new converter;
- with the existing rails, the catalyst loading into the new converter could proceed even before the planned plant shutdown and removal of the existing ammonia converter;
- commissioning of the new horizontal ammonia would be easier as there would few piping configuration changes and operation of the new ammonia converter would also be much easier since there are no major synloop configuration changes.

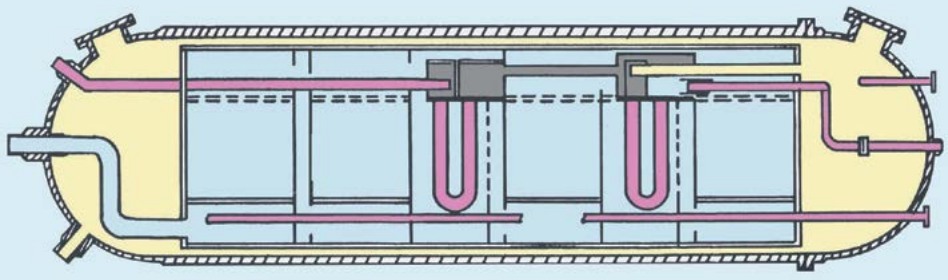
Design considerations

Considering the plot space limitation, KBR recommended the following overall design:

- Increase and optimise the installed catalyst volume from 59.0 m^3 to 69.5 m^3, making it possible to increase the production capacity from 1,300 to 1,400 t/d;
- Reuse the existing support saddles for the new ammonia converter;
- Increase the ammonia converter ID by about 8" from existing of 8'2-½"; and
- Keep the total converter length (tangent to the face of flange) the same as the existing one.

From a thermodynamics perspective, when the installed catalyst volume is the same or nearly the same, a three-bed reactor with two internal heat exchangers is more efficient than the original two- bed design as the synthesis gas is cooled one more time to take advantage of the chemical equilibrium, thereby increasing the conversion of the synthesis gas per pass.

Fig. 10: **KBR'S three bed ammonia converter**



Source: KBR

KBR's proprietary horizontal ammonia converter

KBR's newer three-bed ammonia converter is shown schematically in Fig. 10. The converter contains four beds but is only defined as three reaction stages. The third reaction volume is large, and is therefore divided into two catalyst beds for mechanical reasons. Two interstage heat exchangers and control bypasses are built into the converter, so that the inlet temperature to each of the stages can be controlled individually.

The catalyst beds and the heat exchangers are all built into one basket assembly. The basket can be removed from the converter shell by load bearing wheel trolleys on the rail tracks for catalyst loading and unloading. With this design, there is no need for a heavy crane with a high lift to place the catalyst basket in or out of the converter. Catalyst loading can also be done near ground level.

In operation, the majority of the converter feed provides cooling between the basket and pressure shell, so that the shell is not exposed to the higher temperatures in the catalyst beds. All of the converter feed gas passes through each catalyst bed for maximum conversion and utilisation of the installed volume.

The synthesis gas flow over each catalyst bed is in a downward direction over a relatively thin catalyst bed containing 1.5-3.0 mm catalyst supported on profile wire screen. An inlet distributor has been specifically designed to minimise maldistribution.

Fig. 11: **Installation of new ammonia converter shell**

Mechanical challenges and solutions

Catalyst loading

To save time, the new converter basket was completely loaded separately from the converter.

Bed no.s 3A and 3B were loaded with non pre-reduced catalyst, while bed no.1 and bed no. 2 were loaded with pre-reduced catalyst. During loading in bed no. 1 and bed no. 2, nitrogen purge was used on the basket.

During the catalyst loading process, the basket exit nozzles and recovery nozzles were blocked out to ensure that the nitrogen purge was maintained.

The converter basket was fully loaded in this position and all the man-holes were seal-welded after the complete catalyst loading was done.

Catalyst loading into basket

After ensuring that nitrogen purge was removed from the container, the basket was lifted and positioned on two trolleys.

The front and back trolleys were designed to take the full load of the basket and safely move them to the converter. The site constructions and installation team had created enough room to ensure that scaffolding could be safely put up around the basket to ensure that the catalyst could be loaded into the basket without any issues. Loading catalysts into the basket was quite easy. Like all other KBR horizontal reactors, a large crane is not needed during the loading. The catalyst is vibrated during the loading to maximise and obtain even catalyst densities.

The catalyst loading activities were completed in less than one week, well within the allotted time scheduled. The catalyst loading contractor, KBR, Nutrien FNO and catalyst provider representatives participated in the entire loading process.

Removal of existing ammonia converter

Removal of the existing ammonia converter was another monumental activity requiring meticulous planning. The site has limited space available and it was very difficult to replace a converter with a basket and catalyst inside. The weight of the whole assembly is close to 900 t. To save shutdown time, Nutrien FNO chose a technology called hydra slide as usage of crane was not possible for that area.

Hydra slide is a special technology that is used to perform complex jobs in small cramped spaces where a heavy weight must be moved with utmost precision. A four day window was given to ensure that the old converter shell filled with basket would be removed from the foundation and the new converter brought in position.

The old ammonia converter was removed to a nearby storage area. The nitrogen blanket was kept on the vessel until it was ready for catalyst unloading and disposal.

Installation of new ammonia converter

Following KBR's detailed procedures, the new pressure shell was moved on rails into position (Fig. 11) and placed onto the existing foundation. The installation of the new ammonia converter included the following major steps:

- installation of the converter shell on the existing foundation and making piping tie-ins;
- installation of the new catalyst basket into the pressure shell;
- installation of the head; and
- converter closeout, internal connections and final tie-ins.

New converter shell and basket assembly

Assembly of the new converter shell was the biggest challenge as movement of the basket with a crane at the front of the converter shell was not possible. The basket was already full with catalyst resting on two trolleys. Ensuring that the proper mechanical winch or pull/push mechanism was in place, the new replacement basket on the existing rails was carefully pushed into the new converter shell.

Commissioning

At the same time that the new ammonia converter was ready for commissioning, the front-end start-up was already in progress. Nutrien FNO's commissioning team carried out preliminary leak checks with N_2 pressure at 7 bar g prior to the availability of the makeup syngas. Overnight checks found some minor leaks around the new connection points in the ammonia converter area. After these were repaired, the front-end was ready to send the syngas into the synthesis loop for final leak checking and commissioning of the ammonia converter.

The new converter was commissioned from July 11 to July 17, 2018, with the catalyst reduction proceeding smoothly over four days. The performance of the new ammonia converter exceeded the project objectives and the plant has been operating smoothly ever since. ■

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Starting the digitalisation journey

Optimisation and predictive maintenance algorithms running in cloud-based environments, using IIoT (Industrial Internet of Things) platforms, are starting to shape the future of best-practice operations in chemical plants. In this article we report on cloud-based services for improved plant efficiency and reliability from Topsoe and TOYO.

In today's digital world, companies are facing the question of how to start the digitalisation journey. Long term, new technologies such as artificial intelligence and machine learning will undoubtedly create significant change in how plants are being operated and maintained, but "old-fashioned" expertise on plant operation, together with physical models and simulation tools, when combined with emerging technologies will likely achieve the maximum benefit from both the physical world and the digital world.

While digitalisation is still in its infancy in the oil and gas industry it is expected that digitalisation will significantly change the competitiveness of the industry in the coming years. There is an opportunity for early adopters to differentiate themselves, and in the commoditised and highly competitive syngas-based industry, fertilizer, methanol, syngas and hydrogen producers are constantly looking for opportunities to keep up with the competition, or even better, get ahead.

A cloud-based IIoT infrastructure and secure connectivity to a plant are the technology drivers behind the implementation of cloud-based services. However, it is the knowledge of how a plant is designed, operated, and maintained which makes it possible to develop and deploy the optimal simulations and algorithms using the data extracted from a plant. In addition, the same knowledge is required to develop an insightful user experience for plant personnel.

Industrial operating data

Topsoe, a global leader in catalysis and process technology, has received operating data from syngas-based plants for decades in connection with ongoing technical services activities and when diving into this large pool of data some interesting observations can be made.

When Topsoe receives plant operating data for analysis and optimisation purposes, data reconciliation (error smoothing) is required in order to obtain consistent data that comply with mass and energy balances throughout the plant. Analysing the data originating from almost 400 different plants and the percentage adjustment of the measured value carried out by Topsoe's data reconciliation tool, the average difference between the raw, measured gas composition value and the reconciled one was 13.6%, and 1 out of 10 measurements were adjusted by more than 50%. This clearly demonstrates that measured, raw values in a plant do not provide an entirely accurate picture of the operating conditions, while data reconciliation is an effective tool to get closer to the "truth".

Topsoe has also looked at the operating conditions of the shift reactor, based on industrial data from 245 plants. For shift catalysts, approach to equilibrium (ATE) is used to measure how much of the potential CO conversion is actually realised in a shift reactor. If the ATE is too high, the operating conditions do not ensure full use of the reactor potential, while if it is too low, conversion is limited by equilibrium constraints. It requires a full data reconciliation as well as simulation of the shift reactor temperature profile and equilibrium curve to accurately determine the ATE.

The optimal ATE for a low temperature shift catalyst is 5-10°C regardless of operating conditions, catalyst age and activity, but catalyst charges are often operated outside of this window. In the study, 13% of the calculated ATEs were within the optimal 5-10°C, while for 38% of the data points the LTS was being operated with an ATE in the 0-1°C range.

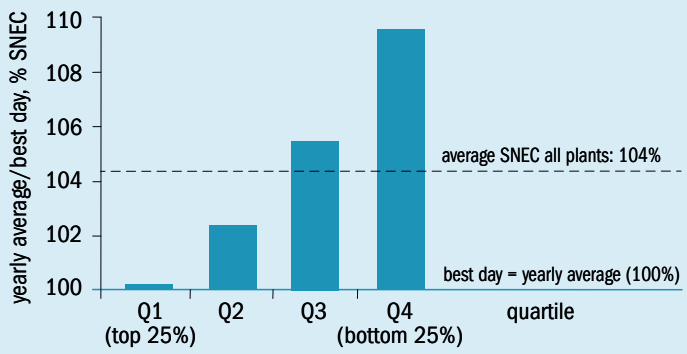
To study this further, Topsoe carried out a survey with 59 plants in 2018, to investigate the reason for not operating the shift catalyst in the optimal window. Many different reasons were observed, with by-pass valve malfunction, dew point limitations, heat exchanger fouling and steam balance considerations as dominant factors. However, for almost half the plants, these factors were not the sole explanation, as a simple adjustment of the inlet temperature could actually improve CO conversion, which is directly impacting ammonia production.

As an example, if a 2,200 t/d ammonia plant operates the LTS catalyst at an inlet temperature which is 5°C lower than the optimal temperature (ATE close to zero), the CO slip from the reactor would typically be 13% higher (increase in CO by 0.04 dry mole %). This would result in a yearly lost ammonia production of 1,550 t (with purge gas recovery). Taking an ammonia price of $340/t, this would correspond to a potential increase in revenue of $550,000 per year, just by optimising this single operating parameter in the plant.

Optimisation potential in ammonia plants

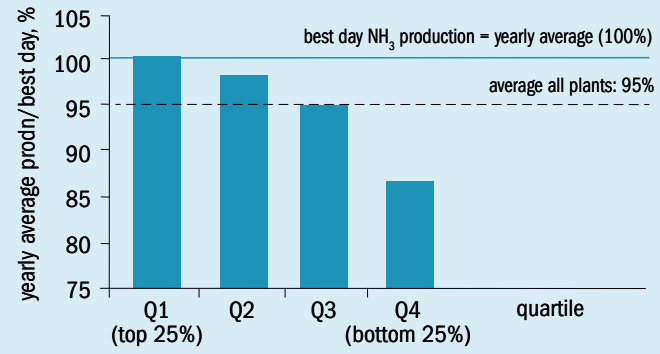
The most important KPIs in relation to plant profitability are the on-stream factor, plant load (production rate), and energy consumption. Maintaining and potentially surpassing these KPIs are one of the main focus areas for plant managers and engineers, and thus it is highly relevant to study if any unrealised potential can be observed.

Fig. 1: **Plant best day specific net energy consumption**



Note: Distribution of plants in 4 quartiles *Source: Topsoe*

Fig. 2: **Plant best production day**



Note: Distribution of plants in 4 quartiles *Source: Topsoe*

In 2018 Topsoe conducted a benchmarking study of 25 ammonia plants to assess how large the optimisation potential is in ammonia plants. The study was based on a full year of operating data from 2017. The plants were both Topsoe design and other designs and the commissioning year ranged from 1960s up to present time.

Based on this study (see Figs 1 and 2), it could be seen that the participating plants on average operate with an energy consumption of 104% compared to their own best day result in 2017. In addition, the plants also produced, on average, 5% less ammonia per day during 2017 compared to their individual top production day (based only on days where the plant was in operation). The study did not look into any unrealised potential beyond best day figures, and some plants would also have additional potential to harvest here.

Another interesting observation from the study was that the gap between a plant's best day of performance and yearly average performance (both production and energy consumption) does not correlate with the age of a plant. It seems to be equally challenging to make every day your "best day" in a modern plant as it is in a vintage plant.

The findings from the benchmarking study showed quite large differences in the onstream factor, plant load (production) and energy consumption between best-in-class plants and worst-in-class. In addition, in many plants it is a challenge to maintain stable operation of best day conditions, leaving an unrealised profit potential of 2-4% of total profit.

Based on the above data analysis of industrial operating data and benchmarking study, combined with Topsoe's general knowledge of plant operation, it was concluded that many plants can improve their main plant KPIs by having direct access to technology licensor and catalyst supplier simulation and optimisation tools, expertise, and guidance on an ongoing basis.

ClearView™ – Topsoe's connected services solution

In order for producers to better harvest the full potential of their plants, Topsoe has developed a concept making simulation and optimisation tools as well as best-practice knowledge available to plant personnel on a daily basis by using an IIoT platform and creating a digital twin of the plant in the cloud.

Topsoe's Connected Services solution, ClearView™ (Fig. 3), is based on automatic upload of plant operating data to an IIoT platform. After data validation, cloud-based simulation tools and analytics software use

Fig. 3: **Illustration of Topsoe connected services solution: ClearView™**

Source: Topsoe

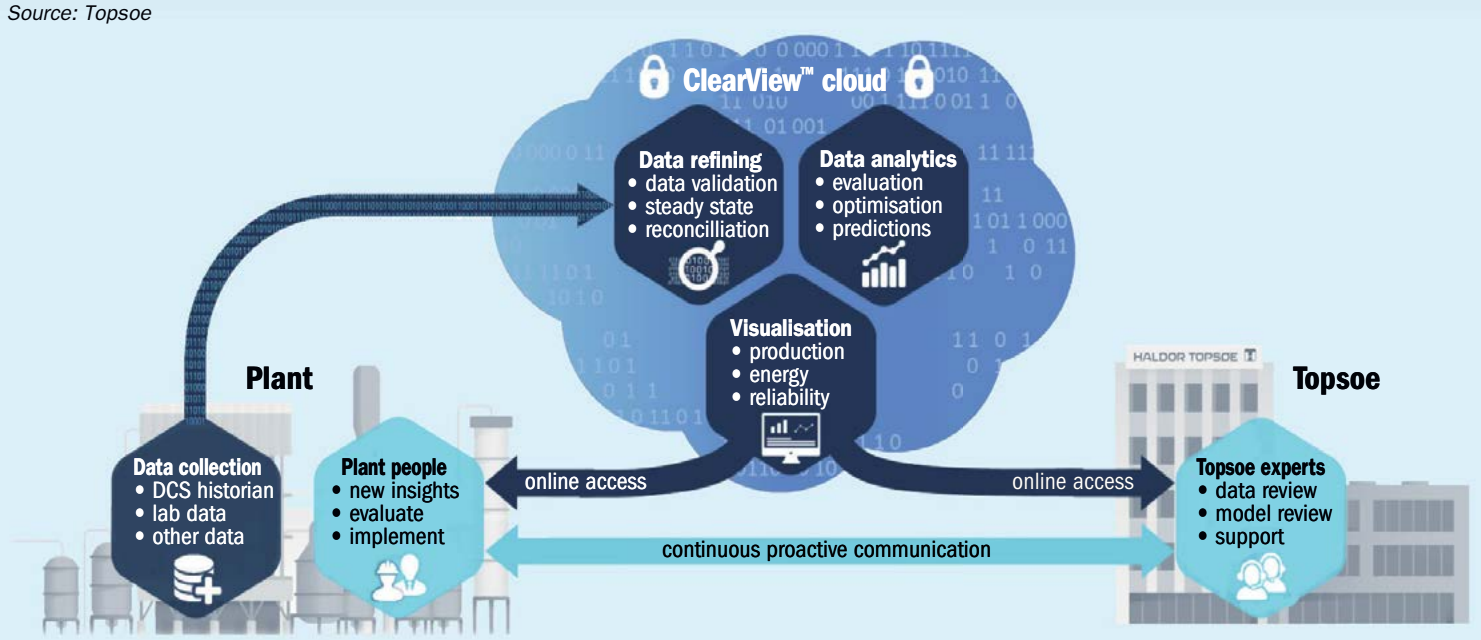
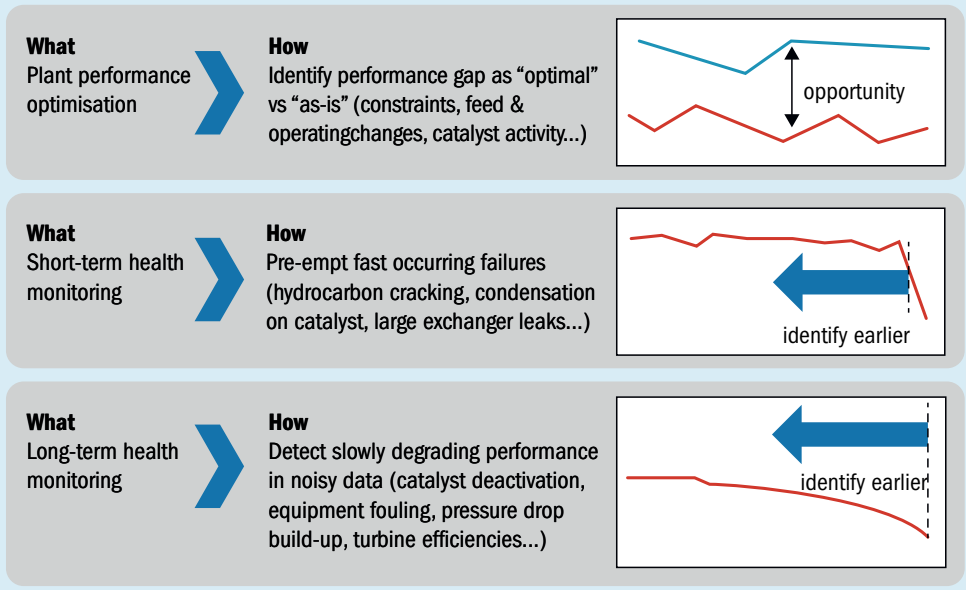


Fig. 4: **ClearView™ identifies optimisation opportunities and performs monitoring**



Source: Topsoe

Topsoe's library of proprietary rigorous models, deep domain knowledge and vast experience within catalysis and process design to evaluate and optimise the plant's current operation. The results are then visualised through online dashboards, giving plant personnel an easy overview of how to optimise plant operation. The software displays whenever there is a gap between the current level for a given operating variable and the optimal setting for that variable. Optimisation is done both with respect to individual catalyst and equipment performance as well as tracking and improving overall plant KPIs. In addition, process-related early event detection features help avoid unplanned downtime. The software is easy to use and does not require extensive training.

Plant performance data will also be monitored by Topsoe experts, who provide continuous support, facilitating a close proactive dialogue with plant personnel to constantly pursue optimisation opportunities and respond to reliability-related alerts as early as possible.

The online dashboards are designed to deliver up-to-date insights directly to the relevant persons and cater to various roles in the plant, including the overall KPI focus of the CEO and plant manager, at a glance alerts for the daily shift engineer and detailed optimisation screens to be used by the technical department.

Competency development of operators and engineers is also addressed in ClearView™, as best practice guidance, background information and theory are embedded into the software. This will help less experienced personnel build up a better fundamental understanding of how the plant operates. Combined with ongoing personal support from the Topsoe team, the negative effects of retirement of senior plant personnel and faster job rotation of younger people can be mitigated.

Examples of what the ClearView™ software does

The ClearView™ software identifies optimisation opportunities and performs monitoring of both fast occurring process-related problems as well as a slowly developing degradation (Fig. 4).

Plant performance optimisation

A full process optimisation calculation can identify the optimal set points, and the ClearView™ software will flag exactly which operating parameters shall be adjusted in order to reach optimum. Optimisation is performed within the identified plant constraints and can be executed with a certain target, i.e.:

- maximum production and lowest energy consumption with fixed feed;
- fixed production and lowest energy consumption with flexible feed;
- minimum energy consumption with fixed production.

But it's not only plant optimisation, connected services can avoid costly downtimes by detecting and solving issues before they become critical.

Short-term health monitoring

A range of incidents can happen with the catalyst or equipment if the operating conditions get outside the recommended operating window. For instance, when getting below the dew point at the LTS reactor inlet, steam will condense on the catalyst, which can lead to catalyst breakage, resulting in high pressure drop and poor flow distribution. The ClearView™ software will show the margin to the dew point at the LTS reactor inlet and prompt an alert if getting too close to the dew point.

Another example is calculation and visualisation of the margin to carbon formation in the hydrogenation reactor in order to prevent carbon formation. Both hot spot temperature and hydrogen recycle are monitored, as a too high temperature and/or too low hydrogen recycle can lead to carbon formation on the catalyst.

Again, an alert is prompted if getting too close to the critical process conditions.

Long-term health monitoring

Some operating parameters will degrade very slowly over time, and it can be difficult to detect early signs of abnormal acceleration in noisy data. Using data reconciliation and normalisation, ClearView™ will continuously monitor such parameters and prompt an alert as soon as a faster than expected degradation is detected. Such parameters include catalyst activities, pressure drops over reactors, fouling factors, and turbine efficiencies. It also gives recommendations on what to do and information on possible root causes.

The building blocks of ClearView™

A number of components are required to support the functionality of ClearView™:

Data upload: Data will normally be uploaded from a process historian and a Laboratory Management Information System (LIMS) through a secure, one-way connection to the IIoT platform. Data collection occurs automatically and ensures that the result reflects the latest available operating conditions.

Data validation: The first step in processing the uploaded data is to refine the quality of the data by so-called data validation. This include gross error detection (readings outside instrument limits), detection of outliners (data points not in line with the rest of the readings from the instrument) and detection of "frozen

values"; all erroneous data points are then omitted from further data processing.

Steady state detection: An algorithm for steady state detection will identify when the plant is in steady state and let data from these periods continue into the software for reconciliation and simulation.

Data reconciliation: The measured operating data always contain some inconsistencies due to fluctuating precision of instruments. It is therefore necessary to perform data reconciliation (error-smoothing) by observing the heat and mass balances through the process steps in the plant and tweaking the numbers to create a consistent set of data, as close to the "truth" as possible.

Process optimisation in a digital twin: A detailed plant model (digital twin) is created using Topsoe proprietary physical models as well as catalyst kinetics and deactivation models based on more than 50+ years of empirical data. Optimisation will be done both with regard to individual catalyst and equipment performance as well as tracking and improving the overall plant KPIs, e.g. production, specific net energy consumption (SNEC) and uptime.

Fault models: In the software, alerts are being triggered by potential problems or areas of improvements defined in an extensive fault model. Once an alert is triggered, the fault model automatically identifies possible causes of the problem or optimisation opportunity. Extensive best practice know-how and expert knowledge is built into these fault models, ensuring early detection of process-related problems and providing an overview of underperforming assets with embedded root cause analysis and recommendations.

Economic optimiser: Specific net energy consumption (SNEC), operating expenses (opex), and profit can be calculated, tracked and optimised from an overall economic model based on actual cost input.

Visualisation dashboards: The results of the simulation and optimisation engine are displayed in online dashboards with an easy-to-understand user interface that provide a quick overview of the current "as is" situation, recommendations on optimisation and possible early event detection alerts. These dashboards are accessible by both plant personnel and Topsoe engineers.

Plant personnel guidance: Guidance and competency development of plant engineers/operators is targeted in so-called "action panels" in the user interface. These screens are being prompted in connection with alerts triggered by the fault model and provide relevant information when it is needed. Such operational guidance and information can contain both theoretical background information as well as best-industry practice advice.

Remote assistance: The Topsoe ClearView™ service include on-going monitoring of the plant operation by experts in Topsoe Support Center and proactive interaction with plant engineers, targeting constant optimisation of performance in an environment where process conditions, catalyst activities, and various constraints change over time. In addition, a joint effort is made to avoid operating problems whenever possible by reacting on the software's early event detection alerts. In situations where an unavoidable issue occurs, Topsoe experts specialised in the specific field in question are available for efficient trouble shooting and root cause analysis together with plant engineers.

A Topsoe Honeywell alliance

When developing cloud-based online optimisation services for industrial plants, many different disciplines are required. Some of these are expertise within engineering and process design, catalysis and technical services, which is the core competencies that Topsoe has developed over decades, but it also requires a range of additional capabilities like connectivity to plants, cyber security, IT architecture, operation and maintenance of an IIoT platform as well as design of software user interfaces and user experiences. For this reason, Topsoe has entered into a strategic alliance with Honeywell, a company which is very much at home when it comes to developing and offering both on-premise and cloud-based software solutions to the oil and gas industry.

Honeywell has already developed such a service concept utilising cloud-based online analytics, which has been sold to above 70 refinery units around the world. The ClearView™ service leverages the same IIoT platform and user interface concept. In addition, the lessons learned by Honeywell for the first 2½ years of commercial operation of the Honeywell Connected Plant Services are being incorporated into the ClearView™ service for maximum customer value in syngas-based plants.

Easy implementation and low maintenance

ClearView™ is offered as a complete end-to-end service, which means that plant personnel can concentrate on taking advantage of the information and support provided as part of this service instead of implementing and managing a large IT project. Limited plant resources are required to get the service up and running, and no large initial investment is required.

The hassle of maintaining models, software and IT infrastructure is avoided. Time and resources in the plant are saved, as everything related to system maintenance, migration, updates, backups, disaster recovery etc. is included in the scope of ClearView™.

The functionality and relevance of the ClearView™ software is kept current by continuous innovation of the online dashboards and underlying calculations. The latest enhancements to the process and fault models are available through online updates as these become available.

Training junior staff

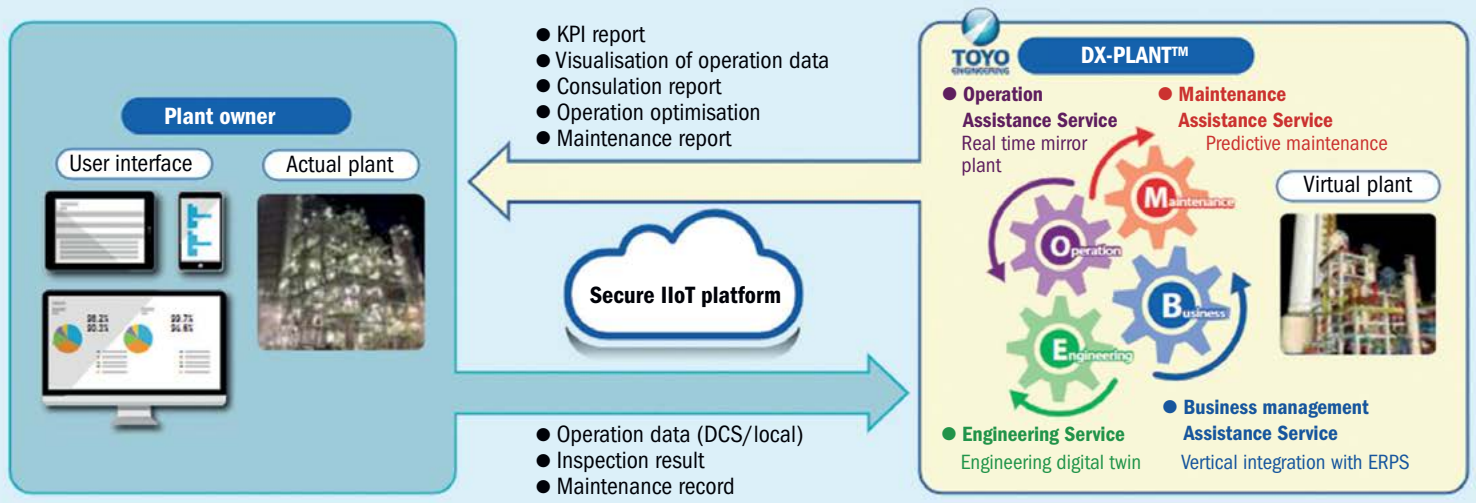
People are the biggest asset in any business and the success of a company depends largely on them. Without knowledgeable engineers and operators companies risk costly downtime, and it can be a real challenge these days with senior plant personnel retiring and faster job rotation of younger employees.

ClearView™ not only helps to keep plants running optimally but can also be used as a learing tool for younger engineers, to improve their understanding of the plant's operation and enhance their knowledge. The software is easy to use and does not require extensive training.

The solution has built in fault models with extensive operational know-how and expert knowledge, ensuring early detection of problems and providing an overview of underperforming assets with embedded root-cause analysis and recommendations. It provides plant engineers and operators with relevant information in the form of easy-to-understand theoretical background as well as best-industry-practice advice.

In addition, junior staff can receive clarification, verification, and follow-up from experienced Topsoe engineers who have access to their online dashboards and provide ongoing support and guidance.

Fig. 5: **DX-PLANT™ architecture**



Source: TOYO

TOYO's digital approach – DX-PLANT™

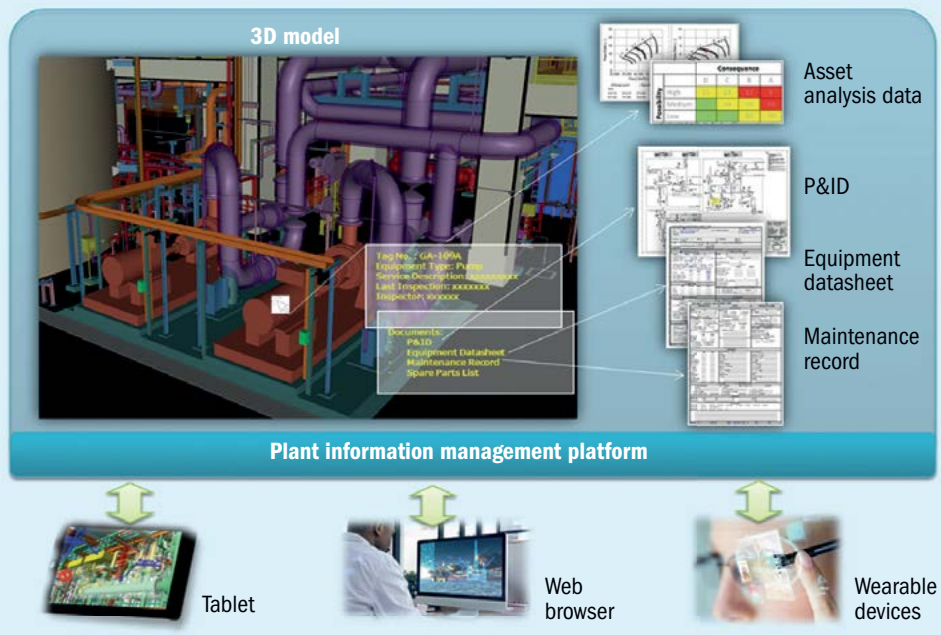
The internet of things (IoT) is at the core of the fourth industrial revolution that is ushering in exciting new technologies. TOYO Engineering Corporation (TOYO), a global leading engineering contractor and urea process licensor, has developed a system for the digital transformation of plants (DX-PLANT™) aimed at maximising client revenue and minimising costs by leveraging TOYO's engineering expertise in chemical process technology and operations for industrial plants, while providing services via a secured platform (Fig. 5). Through DX-PLANT™, TOYO provides solutions for the following four fields: engineering (E), operations (O), maintenance (M) and business (B). The system creates a "digital twin", a virtual plant synchronised with an actual plant based on big data collected from industrial plants.

Nitrogen+Syngas magazine first reported on TOYO's DX-PLANT™ in the July-August 2018 issue. Since then DX-PLANT™ has continued to evolve with an expansion of the platform line-up and and the evolution of new digital solutions.

In November 2016, TOYO commenced the development of DX-PLANT™ with GE (now Baker Hughes, a GE company – BHGE) based on its cloud-based platform for industry (so-called "Predix"). Through conversations with several plant owners, it has become apparent however that some aspire to a digital solution with a "self-made" architecture providing more flexibility than a ready-made platform developed by major platformers. They would prefer to administer the digital system by themselves to cope with future changes in the business environment. They are also concerned about a situation where ready-made applications cannot be customised readily, or its policy or version, which requires the alteration of their existing systems or facilities, is renewed overnight on a certain day.

Taking this concerns into consideration, TOYO decided to expand the DX-PLANT™ line-up and has developed a self-made structure in addition to the existing GE Predix platform to meet end user's requirements. It should be noted that this additional concept is to be structured on a platform that tolerates changes and enables end users to modify the system as they wish. This flexible feature allows clients to manage their systems easily at all times.

Fig. 6: **Engineering information services of DX-PLANT™**



Source: TOYO

Evolution of DX-PLANT™ digital solution

In this section, TOYO's recent progress of each digital solution in terms of the four fields (E/O/M/B) is described.

E: Engineering information sharing and recording

DX-PLANT™ stores not only engineering information such as flow diagrams, data sheets, and drawings, but also historical records for operation and maintenance. The information is integrated into the plant information management system utilising a 3D model which can be accessible from every device and can

be adopted with augmented reality (AR), virtual reality (VR) and/or mixed reality (MR) concepts. Fig. 6 shows an image for the system under development. TOYO is building this application further through collaboration with 3D vendors. Since TOYO is not only a urea process licensor, but also an EPC contractor, it can take advantage of all the detail and as-built design information including vendor's information for implementation. Hence, this integrated information together with the maintenance log and history will enable quick and easy access to the related information from any location whenever needed and provide faster root cause analysis (RCA).

O: Operation assistance service

DX-PLANT™ provides its monitoring, anomaly detection/prediction and operation guidance service for process optimisation on a real-time basis using a model established by big data analysis. For an effective operation service, the data directly obtained from instruments or sensors (e.g. pressure, temperature, flow indication) alone are not sufficient, therefore, it is essential to be able to estimate and evaluate the operation parameters, which are not measured by sensors, for monitoring actual operating conditions. TOYO came up with a soft sensor approach to estimate such unmeasured parameters without sensors. The soft sensor is a type of numerical model where multiple measurable parameters (i.e. direct readings from instruments or sensors) are used to make a formula for the evaluation of irrelative and unmeasurable parameters.

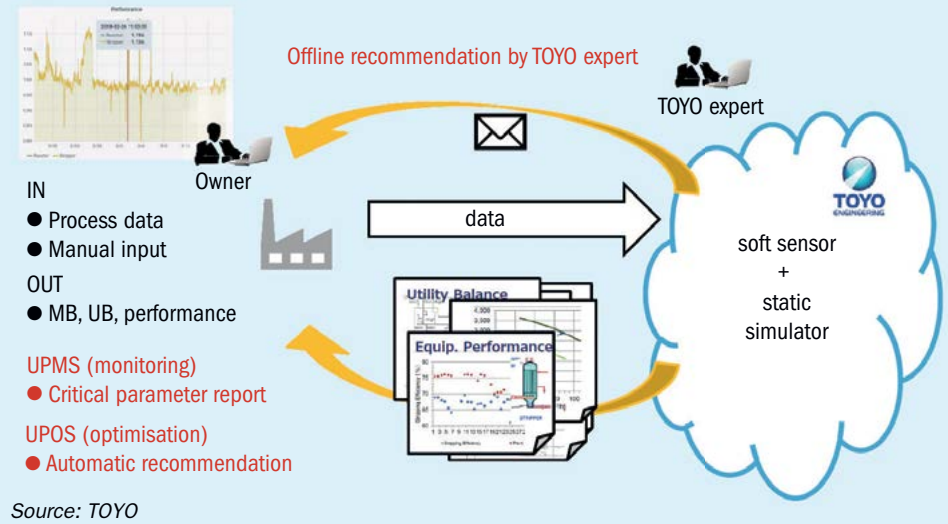
As there are hundreds of direct measurements in a urea plant, the interaction between measurable and unmeasurable parameter(s) needs to be determined in order to build a reliable soft sensor. TOYO's approach to ascertain this interaction uses not only artificial intelligence (AI), but also a logistic approach with expert knowledge. Consequently, TOYO's soft sensor has been developed based on the combined approach of AI and the licensor's expertise (hybrid analysis).

The soft sensor application will be used to determine input parameters to perform a static or dynamic simulation using TOYO's own software, the "hybrid model". In this way, a rigorous and accurate real-time trace of the actual urea plant can be achieved. TOYO presently envisions two services for the "Operation" category – UPMS and UPOS, as outlined below:

- UPMS (urea performance monitoring system): Real-time and on-line monitoring with automatic alert function for end users based on the results of TOYO's hybrid model.
- UPOS (urea performance optimisation system): Seeking optimised conditions by repeated computation with automatic recommendation notification, including advanced anomaly prediction and detection for end users.

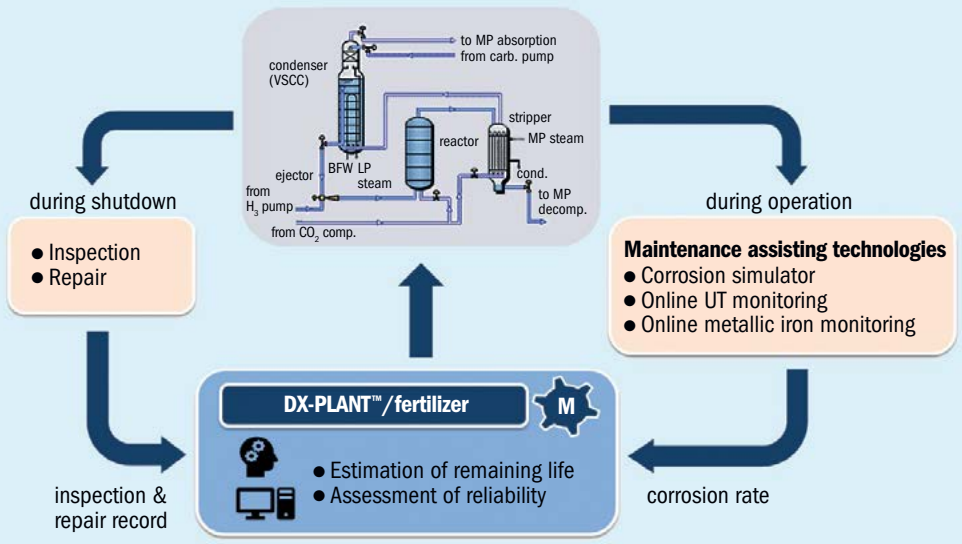
Fig. 7 shows the concept of those services. Based on such novel features, TOYO is able to offer more attractive services to help end users.

Fig. 7: **Operation assistance of DX-PLANT™**



Source: TOYO

Fig. 8: **Maintenance assistance of DX-PLANT™**



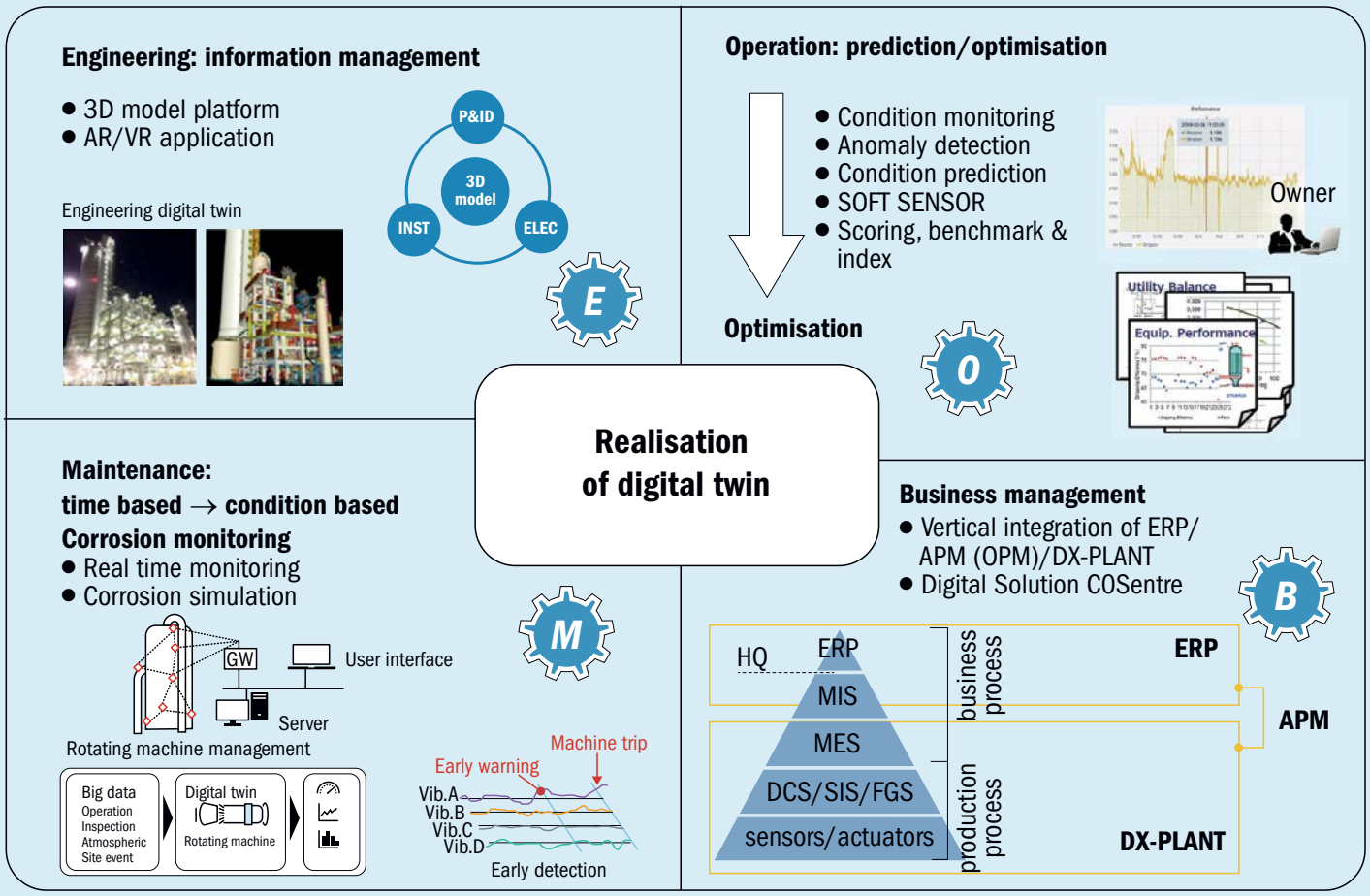
Source: TOYO

M: Maintenance assistance services

DX-PLANT™ offers condition-based maintenance by real-time monitoring and prediction of abnormal conditions for rotating machines and static equipment instead of conventional time-based maintenance. To achieve this, TOYO has developed the following maintenance assisting technologies, especially for high-pressure equipment in the synthesis section of urea plant.

Corrosion simulator: TOYO has developed a corrosion simulator for corrosion prediction based on intensive laboratory test results, immersion tests, electrochemical measurements, and actual data collected from TOYO's commercial urea pants. By giving the operating temperature and oxygen

Fig. 9: **E/O/M/B concept of DX-PLANT™**



Source: TOYO

concentration in the raw material CO_2, the corrosion simulator can calculate the corrosion rate and assess the risk of active corrosion for materials used in the synthesis section.

Online UT (Ultrasonic) monitoring: TOYO is developing an on-line corrosion monitoring system to enhance predictive maintenance for the synthesis section. The aim of the system is to obtain the actual corrosion rate and to evaluate the risk of active corrosion more accurately. Permanently installed ultrasonic sensors at several locations in the synthesis section provide reliable data on the actual thickness and corrosion rate of materials in the section.

Online metallic iron monitoring: The metallic iron content given by the quantitative analysis of Fe, Cr, and Ni dissolved in process fluid can be used to indicate corrosion. It is difficult to measure the thickness of materials suffering from localised corrosion by on-line UT monitoring because it only measures the thickness locally at installed locations. To avoid missing any signs of corrosion, an online metallic iron analyser is installed to detect corrosion as a measure of predictive maintenance.

TOYO's corrosion simulator, on-line UT monitoring, and online metallic iron monitoring are the key technologies for the maintenance assistance service of DX-PLANT™. All digital data together with conventional visual inspection data gathered during shutdown periods, will be added to the system (as shown in Fig. 8) to provide an estimation of remaining life and to assess equipment reliability, which will enhance end users' maintenance activities. This system enables a dynamic risk-based inspection/risk-based maintenance (RBI/RBM) approach and identifies predictive maintenance which can extend turnaround intervals and reduce unscheduled shutdowns.

B: Business management assistance services

DX-PLANT™ integrates corporate and factory management using its stored information of operation and maintenance. This integration system is a vertical structure of enterprise resource planning (ERP), asset performance management (APM) and DX-PLANT™ (as shown in Fig. 9, bottom right), and implements company-wide optimisation to plant management. A virtual warehouse can be created among multiple companies for sharing of stock and spare parts. DX-PLANT™ offers corporate level real-time feedback and helps users to make more appropriate decisions.

Further development of DX Plant™

In December 2017, TOYO launched DX-PLANT™ for PT Pupuk Sriwidjaja Palembang (PUSRI). For the next phase of development, TOYO is working on providing solutions for various needs of clients. DX-PLANT™ is about to be deployed in several plants, and TOYO will continue to move forward to expand DX-PLANT™ applications to other process fields such as petrochemical plants or other industries. Once several plants are connected on the DX-PLANT™ platform, TOYO will establish a "Digital Solution Center" by connecting multiple plants to provide the total solution to end users. TOYO's integrated IoT solution provides a new benchmark for plant governance. ■

Reference

1. Fjording M. (Topsoe): "Improving efficiency and reliability with cloud-based connected services", Nitrogen+Syngas 2019 Conference, Berlin, Germany (Feb 2019).

Effect of SMR tunnels on flue gas flow

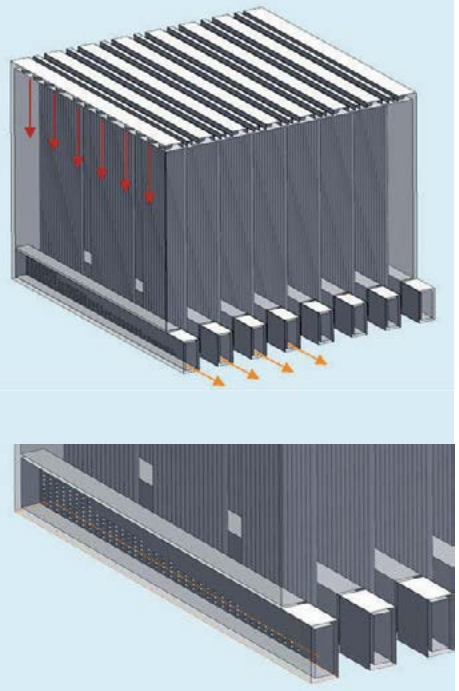
The concept that running a reformer without tunnels can decrease overall efficiency is well understood in the industry. Blasch Precision Ceramics has carried out a computational fluid dynamic study on the effect of operating a steam methane reforming furnace without one of the flue gas tunnels. In this article the resultant flue gas flow field is analysed looking at temperature profiles, residence time distribution, areas of recirculation, and predictive conversion effectiveness.

Scope of Study

A computational fluid dynamics (CFD) study was performed by Blasch Precision Ceramics on a theoretical reforming furnace (Figs 1 and 2) to determine the comparative results of flow uniformity in flue gas tunnels with and without a standing tunnel in the outer position. The furnace modelled is 13 x 16 x 16 m (height x width x length). Along the floor of the furnace run eight flue gas tunnels, 16 m in length and 1.8 m height with a 66 cm internal tunnel width. 96 flue gas burners are modelled to provide heat to 336 catalyst tubes.

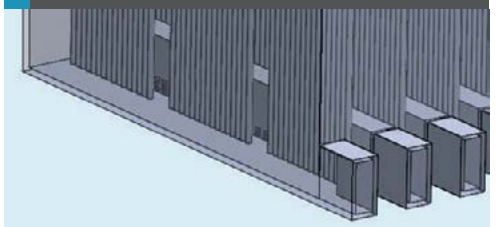
Two furnace models were compared, one running a full set of eight tunnels, and another without the outer tunnel but with the other seven tunnels. This is intended to replicate a situation where a tunnel has collapsed during a campaign, and at a maintenance outage the debris was removed but a new tunnel was not constructed, likely with the plan to rebuild the tunnel during a future turnaround with more time available for construction.

Fig. 1: **Reforming furnace model with all tunnels**



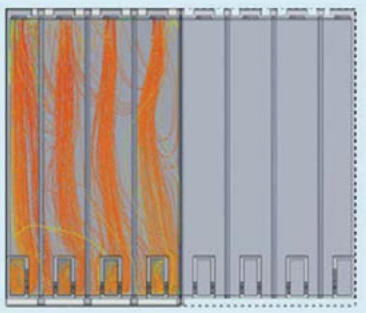
Source: Blasch

Fig. 2: **Reforming furnace model with no outer tunnel**



Source: Blasch

Fig. 3: **Theoretical reforming furnace showing some recirculation**



Source: Blasch

Mesh/CFD inputs

The overall size of the furnace in the model is large enough to dictate a coarse mesh size, and the detail required for desired outputs is small enough to dictate a fine mesh size, so a variable mesh approach was used. To increase the refinement level for this study a symmetric plane condition was used in the middle of the furnace, between tunnels 4 and 5. Because the main focus of the study was the area around tunnel 1, the outermost tunnel, a finer mesh was applied in that area.

Flue gas enters the model through the burner openings on the furnace ceiling travels downward towards the floor, entering the tunnels if present, and then exits the model from the openings at the end of the tunnels.

For this analysis the reaction occurring inside of the catalyst tubes is not being modelled, and instead the tubes are assumed to act as a heat sink with convection governed by standard heat transfer equations. It is important to note that this assumption will limit the result of this model's accuracy when it comes to absolute temperatures, particularly in areas directly adjacent to the catalyst tubes. Results from this model pertaining to absolute temperatures should be considered comparative only.

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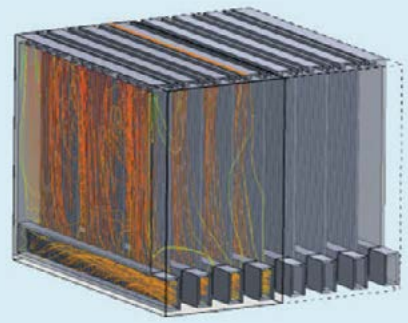
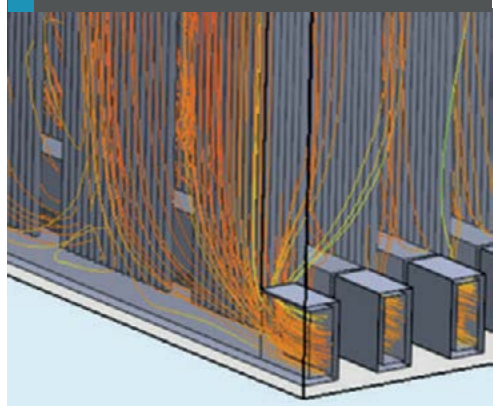
Fig. 4: **Non perfect flow field of reforming furnace**



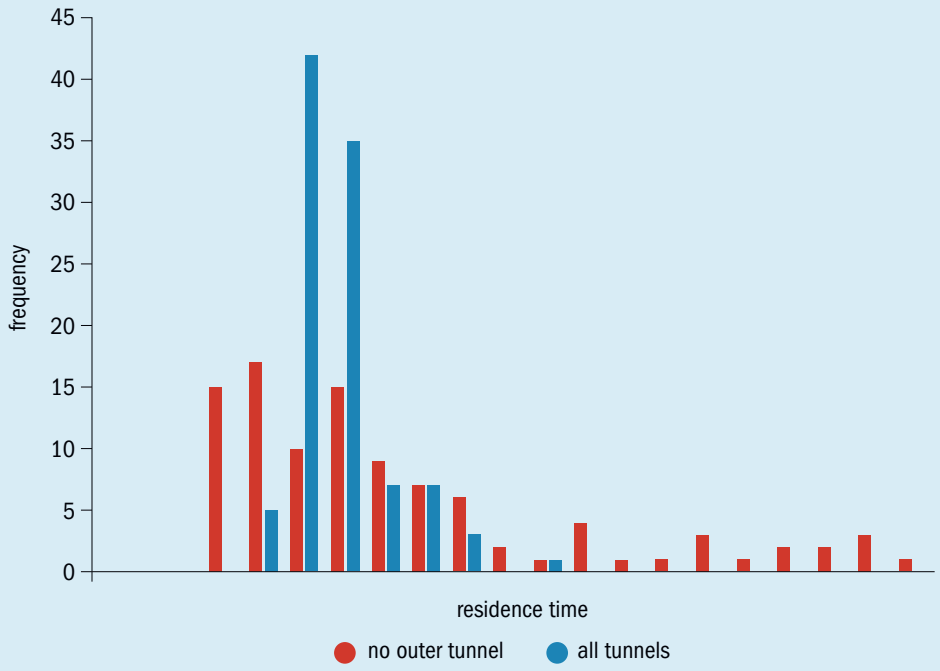
Source: Blasch

Fig. 5: **Non uniform flow conditions for reforming furnace with no outer tunnel**



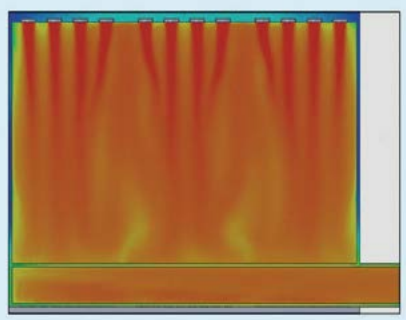
Source: Blasch

Fig. 6: **Residence time of flue gas**



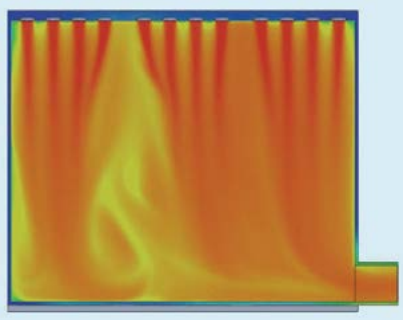
Source: Blasch

Fig. 7: **Reforming furnace with all tunnels**



Source: Blasch

Fig. 8: **Reforming furnace with no outer tunnel**



Source: Blasch

Results

Reforming furnace with all tunnels

Flow trajectories from the CFD results show that a reforming furnace operating with all tunnels will have a flow field covering the entire furnace, as designed. This provides an accurate control case.

This theoretical reforming furnace shows some areas of recirculation and does not have a perfect flow field, suggesting that it could benefit from burner and tunnel port balancing to optimise the overall furnace profile (Figs 3 and 4).

Residence time of the flue gas coming through the burners over the top of the outer tunnel can be measured in this model by running a secondary particle study. This study simulates a single particle being inserting into the furnace through a burner inlet and then measures the time it takes for that particle to travel through the furnace to the exit. This particle insertion is replicated hundreds of times across the 12 burners over the top of the outer tunnel, and then charted in a histogram to show overall distribution. Uniform residence time is an important aspect of furnace efficiency, as total heat transfer is dependent on time.

A temperature profile can be used to view the uniformity within the reforming furnace. A profile inserted vertically in the middle of the outer tunnel shows the flow field of the burners (Fig. 7).

The temperature in each tunnel can be represented graphically by taking data points along the length of the reformer, 18 inches above the furnace floor. The tunnels can each be graphed with an individual line plot as shown in the below graph. As previously mentioned, this analysis is run with assumption that the catalyst tubes will act as a simple heat sink instead of a complex reaction location, so the absolute temperatures shown here at much more stable that field results typically indicate.

Reforming furnace without an outer tunnel

The second furnace can be modelled without the outer tunnel as previously described, and analysed for all of the same furnace conditions. Flow trajectories show that a reforming furnace without an outer tunnel will have non uniform flow conditions (Fig. 5).

These non-uniform conditions result in a wider range on a residence time graph (Fig. 6). The blue bars represent the control furnace with all tunnels, and the red bars represent the furnace without an

outer tunnel. The absence of the outer tunnel allows for a portion of the flue gas to exit the furnace very quickly, and creates recirculation of another portion of the flue gas leading to a wide range of residence times. It can also be noted that flue gas exiting the outer furnace opening is not limited to the burners in the outer row, but also from adjacent burners within the furnace.

A temperature profile inserted vertically in the middle of the outer tunnel shows the flow field of the burners (Fig. 8). The furnace without an outer tunnel shows a clear bias of flow from the first two banks of burners towards the exit, creating recirculation of the remaining flow from the third burner bank.

Average temperature inside of the furnace with all tunnels intact is 956°C. The average temperature inside of the furnace without an outer tunnel is 916°C, and the average temperature inside of the area where an outer tunnel would be is 836°C.

The gas composition output of a SMR is directly related to the temperature. The expected composition can be calculated for a tunnel with all tunnels (956°C) and a tunnel without outer tunnel (916°C and 836°C). In order to do this a number of reaching assumptions must be made. First, the assumption that the flue gas temperature at the points measured is the exact temperature of the reforming gas composition inside the tubes. This is of course not the case, but since both furnace outputs are being treated with the same assumption it should provide comparative information. Second, the temperature data points taken for this CFD are near the furnace floor where the tunnels are present, and it is assumed that the temperature near the roof of the furnace is identical in both models, so both of these areas are averaged together when looking at gas composition output. This is an area where more analysis could be utilised to get an even more accurate result.

Taking into mind the above-mentioned assumptions, this CFD model suggests that the percentage of hydrogen in the gas composition of the furnace output decreases if all the tunnels are not in place, as a result of the decreased furnace temperature. The percentage of hydrogen could decrease by 9.7% in the furnace area adjacent to the missing outer tunnel, and the percentage of hydrogen could decrease by 0.95% across the entire of the furnace. A chemical plant producing 2,000 t/d of ammonia could theoretically decrease production by 19 t; if the primary reforming output is a limiting factor. If the reforming furnace is run for a year before the tunnel is replaced the resultant production loss would be 6,916 t, which at a bulk sale price of $300/t, the theoretical annual impact of running without an outer tunnel is $2,074,800.

Conclusion

Flue gas tunnels play an important role in the overall distribution of flow in a reforming furnace. Running a furnace without an outer tunnel results in a wider distribution of residence time, as some of the flue gas from the front burner banks is able to exit the furnace very quickly and other flue gas from the back-burner banks creates recirculation zones. This in turn reduces the uniformity of temperature distribution across the reforming furnace, which directly influences the gas composition output.

The theoretical annual economic impact of running a SMR without an outer tunnel is significant. ■

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