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March | April 2015

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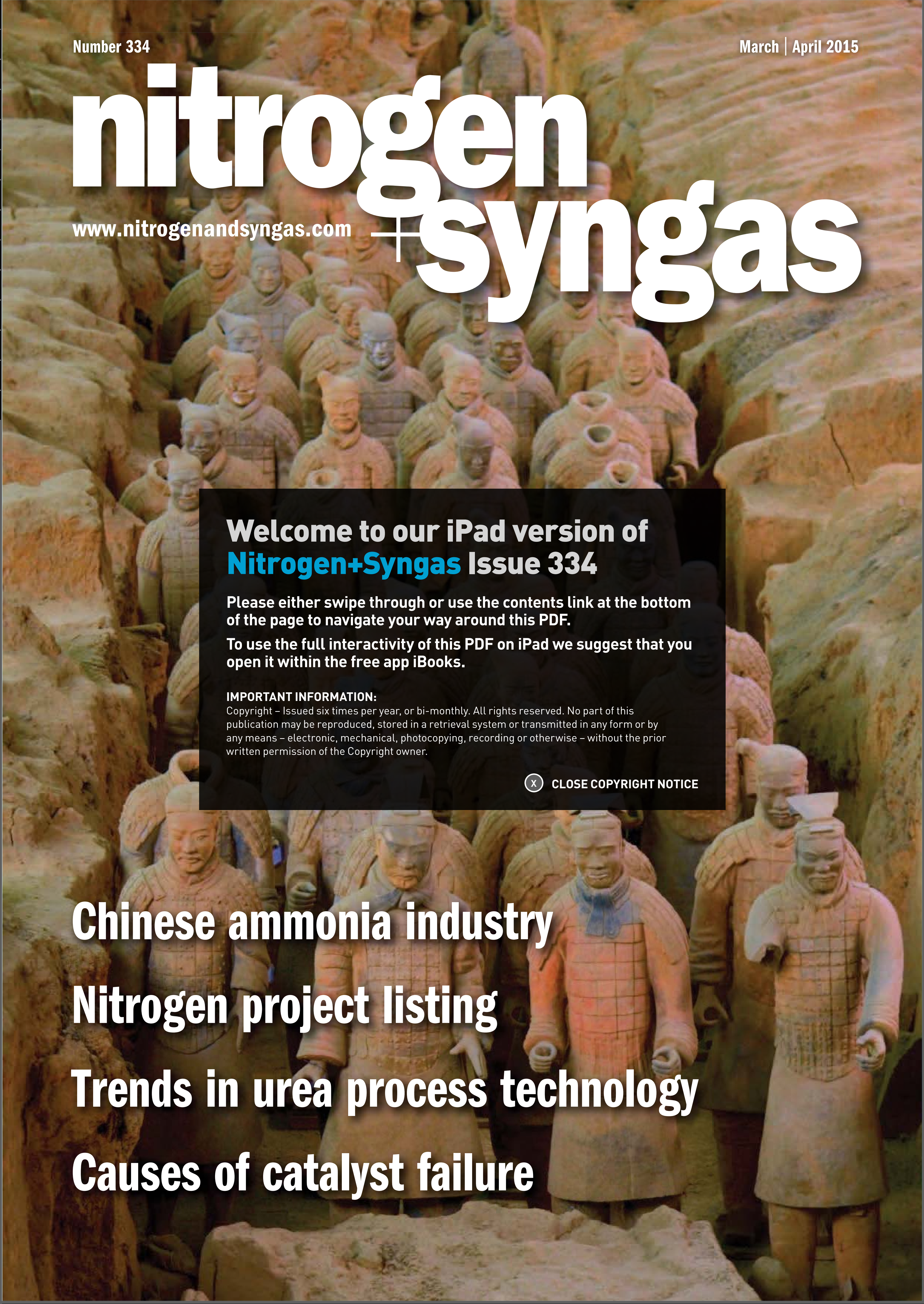

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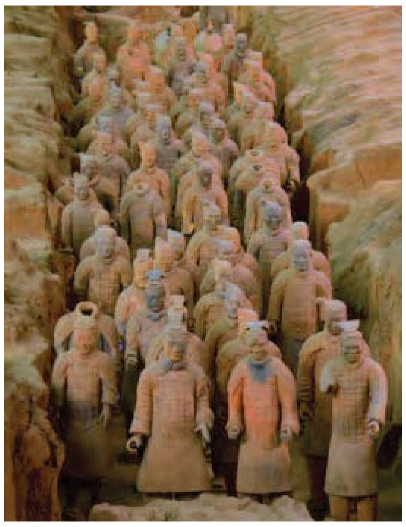

**Cover:** *Detailed view of the famous Terracotta Army in China. Pavel Dudek/Shutterstock.com*

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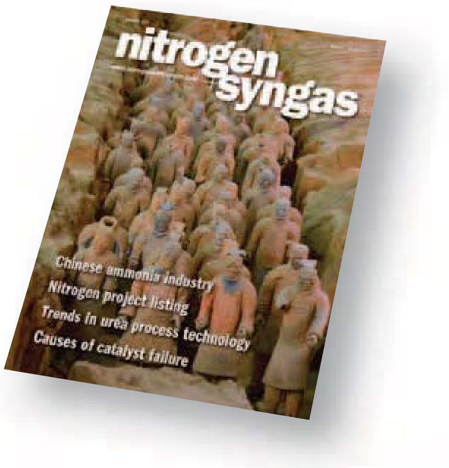
# India ducks urea subsidy reform



The start of March saw the unveiling of India's Union Budget for 2015-16. The budget was extensively trailed as being pro-business, and it certainly made a number of eye-catching moves for cutting the budget deficit, reforming taxes (a single goods and services tax, for example), streamlining India's endemic bureaucracy and tackling its equally endemic corruption. Cuts to corporation tax and improvements to infrastructure were also welcome, but on the vexed issue of agricultural subsidies the news seemed to be 'steady as she goes' for the time being. There had been anticipation that the maximum retail price for urea would be increased by 10-20%, and that a timeline might emerge for urea's eventual inclusion in the existing nutrient-based subsidy (NBS) scheme. In the event, neither of these things occurred, and in the absence of them, the NBS will continue to effectively privilege urea at the expense of other fertilizers, leading to exactly the kind of imbalance in nutrient applications that it was designed to cure, with potential serious effects upon agricultural productivity and nutrient depletion. And in the meantime, higher gas prices and rail freight costs have increased the cost of domestic urea production in India, potentially forcing the government to increase subsidy payments to producers, rather than cut them as many had hoped (although there are still many outstanding payments to producers for previous years which have not yet been paid). Urea used to occupy about 40% of all fertilizer subsidies, but now this has increased to 70%, as fertilizers like DAP have moved closer to market rates.

> **“The NBS will continue to effectively privilege urea at the expense of other fertilizers.**

Furthermore, there are plans in circulation to reduce the priority that domestic urea producers get in terms of natural gas allocation, which would reduce India's production of urea at the same time that naphtha-based plants are being forced to close, and imports are steadily increasing. Plans to develop more domestic urea capacity are manifold, but the difficulty of securing gas allocation makes all of them uncertain. The increase in gas prices to domestic producers from $4.20/MMBtu to $5.60/MMBtu has exacerbated the problem, although rising gas prices may help draw more supply into the gas market, something that has become a necessity in many major gas consuming countries.

The government can be forgiven for prioritising India's long-term growth, which had been lagging behind China's, but which now seems to be accelerating at a time when China's has been flagging. Furthermore, the move towards a system of direct payments to farmers rather than producers seems to be in hand, and longer term may offer a way out of the current quagmire by allowing fertilizer prices to find market rates, encouraging new supply into the domestic market. The government says that in three years' time, there will be complete digitisation of land records and soil health cards for every farmer, and bank accounts set up under the Jan Dhan Yojana scheme. At that time, import controls (currently on the three major government importers are allowed to import urea from overseas) may be relaxed or even done away with.

Until then, however, little change seems to be in sight. The question of agricultural subsidies is a difficult one for Indian governments, especially one that needs rural votes, but it is nevertheless a disappointment that a reformist government like Modhi's was not able to make some move in that direction at a time when its political capital is at its highest. ■

*Richard Hands, Editor*

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# Price trends

## NATURAL GAS

US natural gas consumption for power generation reached record monthly levels in both January and February, driven by increased consumption in the eastern half of the country. Gas demand for power production averaged 23.1 bcf/d, 3.6 bcf/d higher than the average for the previous five years. Extremely cold weather, especially across the east of the country, has been a major contributor to this, but the gradual shift from coal-fired generation to gas-fired generation over the past few years has also played a large part. Indeed, the cold weather did not extend to the west of the country, where milder conditions prevailed, and Henry Hub prices continued to drop, reaching $2.68/MMBtu at the end of January, and rising only slightly to $2.77/MMBtu during February. Gas in storage remained within historical norms.

In Europe, UK National Balance Point prices were relatively steady around the 50p/therm mark ($7.50/MMBtu). European gas prices have been impacted by relatively weak demand and the gradual transition away from long term, oil indexed pricing, as well as the fall in oil prices, bringing greater volatility, but for the moment, lower prices. Contract prices out to Q2 and Q3 2015 are in the $6-7.00/MMBtu range.

Ukraine has had to drastically increase gas prices to domestic consumers as part of an EU finance package. Gas prices for ammonia producers remain high, at almost $10/MMBtu.

China has been cutting natural gas prices to industrial users as part of the government's desire to make domestic gas prices more responsive to global market conditions. This has had a knock-on effect on LNG prices as China attempts to get out of some long-term LNG purchase contracts on the back of slower demand growth than expected (albeit still at 8% year on year). Although Japan took record LNG volumes during January and February, Japanese spot LNG prices dropped to $7.60/MMBtu, some of the lowest seen, and there are forecasts this could fall to $6.25/MMBtu by Q3 2015.

## AMMONIA

The ammonia price slide that began in November continued to fall into the New Year. There seems to be plenty of supply chasing not enough buyers, buyers who often continued to hold back from purchasing in the hope and expectations of further falls. At the start of January Black Sea prices were in the range of $450-470/t f.o.b., but by the end of the month they were below $400/t, a point at which buying interest finally returned, and there was some stability at that price level throughout February.

Middle East prices stayed high for longer, ending January at $480/t f.o.b. Arabian Gulf, not much lower than at the start of the month, but by the end of February they too were in the $400-420/t region.

The story was the same in all major markets, with the Tampa settlement for February dropping by $50 to $495 c.fr. Asian markets were as usual traditionally quiet around the Chinese New Year holiday.

There are all indications that the market has bottomed out now. Seasonal buying is likely to pick up again in March, rising phosphate prices should boost DAP output, and there will be reduced availability out of the Arabian Gulf once the Safco V urea plant starts up.

Table 1: **Price indications**

| **Cash equivalent** | **mid-Jan** | **mid-Nov** | **mid-Sept** | **mid-July** |
|---|---|---|---|---|
| **Ammonia** ($/t) | | | | |
| f.o.b. Caribbean | 440-505 | 615 | 530 | 480 |
| f.o.b. Arab Gulf | 470-490 | 635 | 583-600 | 440-460 |
| c.fr N.W. Europe | 480-535 | 650-710 | 570-620 | 507-527 |
| c.fr India | 530-570 | 555-630 | 550-570 | 485-537 |
| **Urea** ($/t) | | | | |
| f.o.b. bulk Black Sea | 320-325 | 315-318 | 318-325 | 290-307 |
| f.o.b. bulk Arab Gulf* | 320-325 | 307-320 | 335-360 | 305-318 |
| f.o.b. bulk Caribbean (granular) | 325-335 | 340-350 | 350-355 | 345-355 |
| f.o.b. bagged China | 280-285 | 289-294 | 285-290 | 258-260 |
| **DAP** ($/t) | | | | |
| f.o.b. bulk US Gulf | 485 | 460 | 480 | 490-511 |
| **UAN** (€/tonne) | | | | |
| f.o.t. ex-tank Rouen, 30%N | 200-227 | 200-203 | 194-198 | 186-188 |

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

*Source: Fertilizer Week*

## UREA

January was a relatively subdued month in urea markets, with prices softening slightly over the course of it from $320/t f.o.b. Yuzhnyy towards $305-310/t. There was some anticipation that urea prices would fall as oil markets and in turn natural gas markets had, and the weakening euro also impacted upon buying interest in Europe. Although supply out of Egypt has been curtailed by natural gas supply issues, there was ample availability at lower prices from other regions.

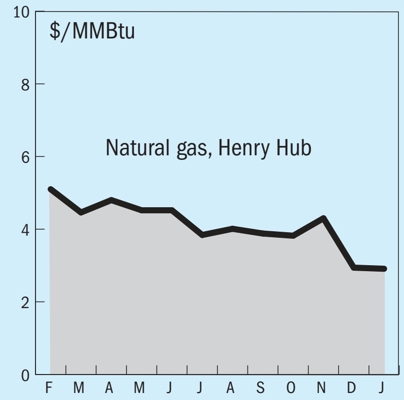
As it often does, Indian buying became the major talking point for traders at the end of January, offering some support for Chinese prices, amongst others. MMTC received over 3 million tonnes of offers for its January 27th tender, and took up just over 1.0 million tonnes of those from China alone at a netback of around $285/t f.o.b. While Black Sea producers tried to hold out for higher prices, there was considerable pressure fo them to drop rates to $300/t and below.

Chinese markets were quiet during the New Year, with little trading in evidence, but falling prices in the west are believed to be likely to drag markets down. Middle East granular prices also softened, with netbacks falling below $290/t f.o.b. by the end of February.

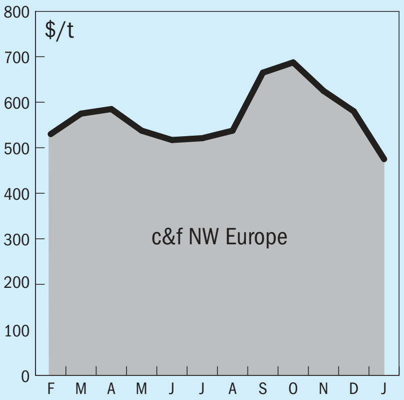
In the US, New Orleans barge prices dropped towards $305/st f,o,b, The market has been subdued by the large import volumes that arrived during February and into march. US imports for March could be down on last year, but overall tonnages in advance of the spring application season seem to be higher, and there are expectations of further price falls into Q2. ■

## END OF MONTH SPOT PRICES

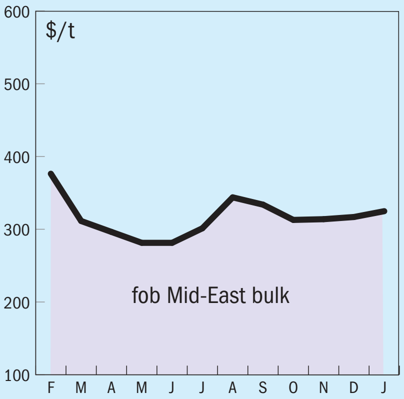
### natural gas



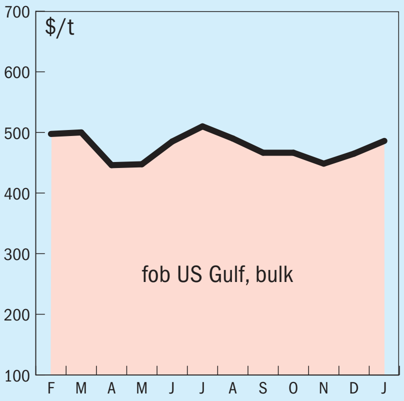
### ammonia



### urea



### diammonium phosphate



## METHANOL Mike Nash, Global Business Director, IHS Chemical

The February contract natural gas reference price was settled at $2.90/MMBtu for Texas, and $2.96/MMBtu for Louisiana, down three cents from January. Spot US methanol activity was moderate, with prices in a wide range from $1.05–1.12/gallon, with talk for April in a similar range, clearly still elevated compared to weighted average prices for February ($1.04/gallon). The driver for this has been a general sense of restricted supply resulting from two US units being offline (OCI Beaumont and Lyondell), and the nearly constant ~15% gas restrictions placed on Trinidadian units, as well as the turnaround for AMPCO in west Africa. In South America, Venezuela is estimated to still be running at approximately 65% on average. Methanex's 840,000 t/a Chilean unit is estimated to be operating around 15% of nameplate on a gas tolling arrangement.

Logistics have also been a challenge within North America with heavy winter weather causing delays for truck and rail movements, while melting snow has led to higher water levels on the rivers to the south impacting barge movements. Overall demand remains flat for the transition period between winter and summer demand. Continued cold weather in North America has driven up winter applications again, but spring is around the corner and moving more methanol from the Gulf will likely mean that those tons will arrive about the time that warmer weather is expected. Construction demand continues to stall with the weather as well. Official posted reference prices from major producers for March are $1.25/gallon for Methanex and $1.23/gallon for Southern Chemical. IHS Chemical's contract net transaction price for March is officially posted at $1.241/gallon (nominal $413 per metric ton).

Prices in Europe rose back in line with those seen in Asia. The full-year demand outlook for Europe remains fairly low but despite this, methanol consumption rates appear healthy. EMethanex in Damietta, Egypt, was affected by significant gas restrictions in January related to a pipeline explosion in western Egypt. Availability of natural gas continues to restrict operations in Egypt. In Russia, Nevinnomyssk will begin a 30 day planned turnaround in March and Shchekinoazot will undergo planned maintenance from 24 April, to last one month. A turnaround at a unit in Saudi Arabia is underway. European inventories are moderate but not as high as at the start of the year. Iranian imports continue to flow into Italy, but storage is heavily restricted for Iranian imports into Rotterdam. Availability from Saudi Arabia and Southeast Asia is lower than expected for March, which has reduced volumes offered to buyers in the Mediterranean and Northwest Europe overall.

Chinese domestic prices have been fluctuating. The inland production operating rate is decreasing as some major units are down for maintenance in March and April. The total volume in coastal main ports is about 600,000t – a manageable level. The China average operating rate decreased to 49% of nameplate capacity, following some mid-to-large sized coal-based methanol producers' outages or units slowing down for upcoming planned turnarounds. The operating rate is likely to remain at a low level for most of March. Spot buying interest from the formaldehyde and DME sectors is good on the back of end-users building up their inventory after the Chinese New Year holiday. Market prices of most key derivatives improved. Demand into formaldehyde is picking up on the back of an increased buying sentiment from end-users and demand into DME improved in most provinces except those in South China.

In Korea, the domestic market remains stable. End-user inventory is decreasing slightly. A 10,000t non-Iranian deal was concluded at $300-305/t for April arrival. Formula price discussions involve a 1.0%-1.5% premium. In Taiwan, end-users are under pressure to honour contract volumes. End-user inventory is high. The spot price is offered in the range of $300-305/t for non-Iranian cargo. In Southeast Asia, Petronas's large 1.7 million t/a unit remains offline. The BMC and KMI units are running at high rates. Buyers are looking for March arrivals but there are not many offers in the market. The major discussion range is $290-300/t. The arbitrage window is still closed between China and Southeast Asia. ■

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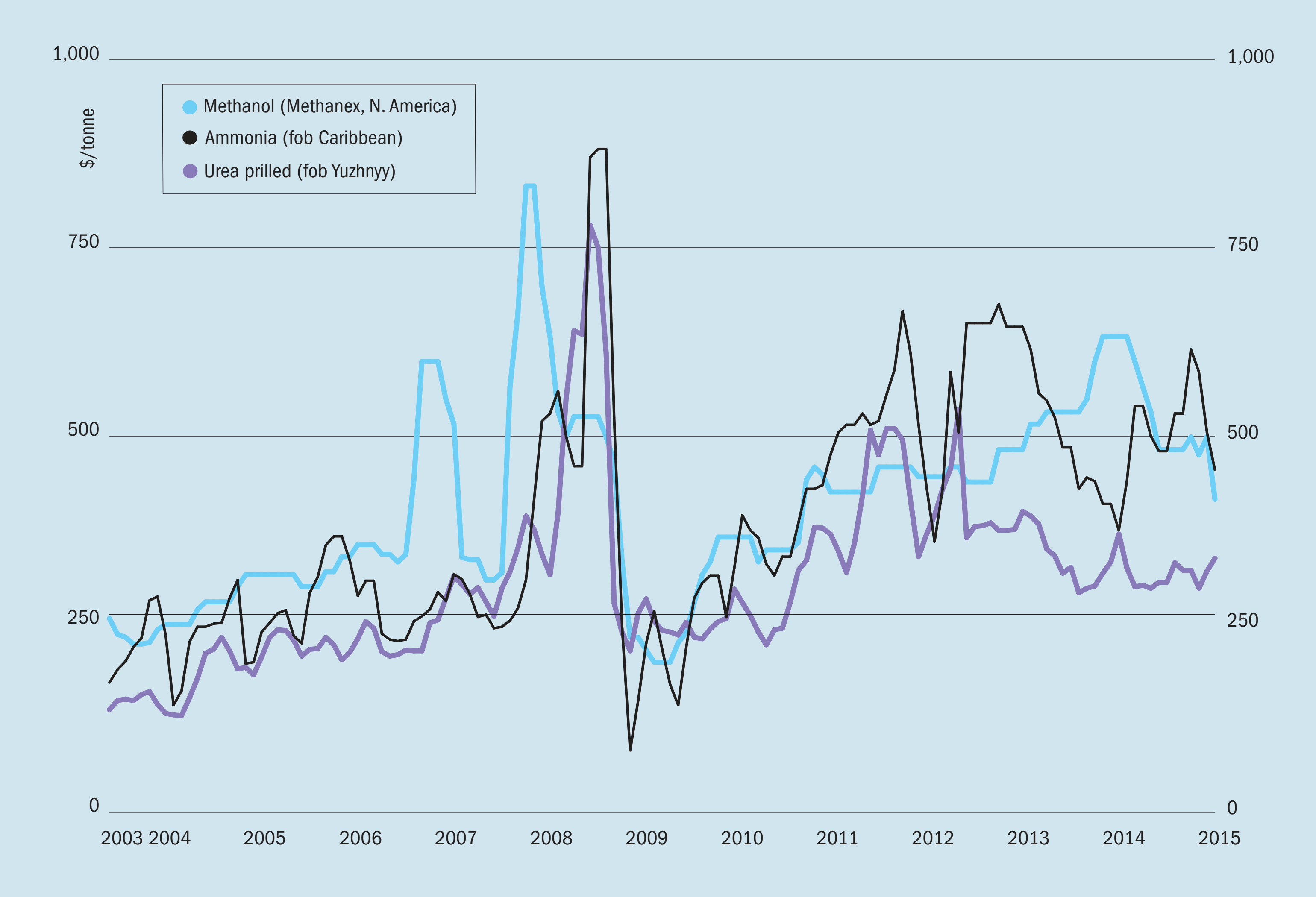
# Market outlook

**Historical price trends** $/tonne



## AMMONIA

- Ammonia values slipped in late January, plateauing at around $400/t f.o.b. Yuzhny. Markets remained quiet however during the first half of February.
- OCP, Morocco has remained a keen buyer and is reported to have paid between $435-445/t cfr for a recent shipment from Algeria.
- Ammonia buyers in India have held back from making major purchases while they await a clearer picture of the likely price direction. IFFCO is receiving a contract cargo from Sabic under a formula pricing arrangement. The most recent price ideas were $510-520/t cfr, based on recent deliveries.
- In general it seems the market seems to have bottomed out, and likely that seasonal buying is likely to pick up again in March as rising phosphate prices boost DAP output and the applicaton season begins.
- The start-up of Safco V should also reduce availability out of the Middle East.

## UREA

- Urea activity was also subdued for much of February. Traders which had concluded aggressive sales based on the prospects for Black Sea availability in the low-$300s/t f.o.b. have yet to recoup their outlays, and late February/early March prices were expected to slip below the $300/t benchmark.
- China has secured large volumes of prilled urea for shipment to India, reducing product availability elsewhere. Prices there were reported to be falling to the $290s/t f.o.b.
- Chinese New Year has kept prices level but the expectation was for further price falls into March.
- Granular urea netbacks to Middle Eastern suppliers fell sharply, reflecting US market weakness. Suppliers in the region have been faced with returns of around $290/t f.o.b. or lower and are expected to seek higher yields from European markets, where netbacks have been above $305/t f.o.b.
- FSU prilled values have also lost ground as traders aggressively pursued the limited amount available business. Some sales were concluded at prices netting back to $280/t f.o.b.

## METHANOL

- US methanol outages are set to ease, especially with the start-up and gradual ramp-up of production at the new Methanex plant at Geismar.
- Logistical issues caused by winter weather are also easing in North America.
- Volumes of Chinese methanol are also expected on the market over the coming month.
- However, demand into derivatives seems to continue to be strong in most major markets.
- As oil prices have stabilised, so methanol rates appear to have done likewise.
- Chinese energy applications remain the marginal buyer, and as oil prices rise so should methanol prices. ■

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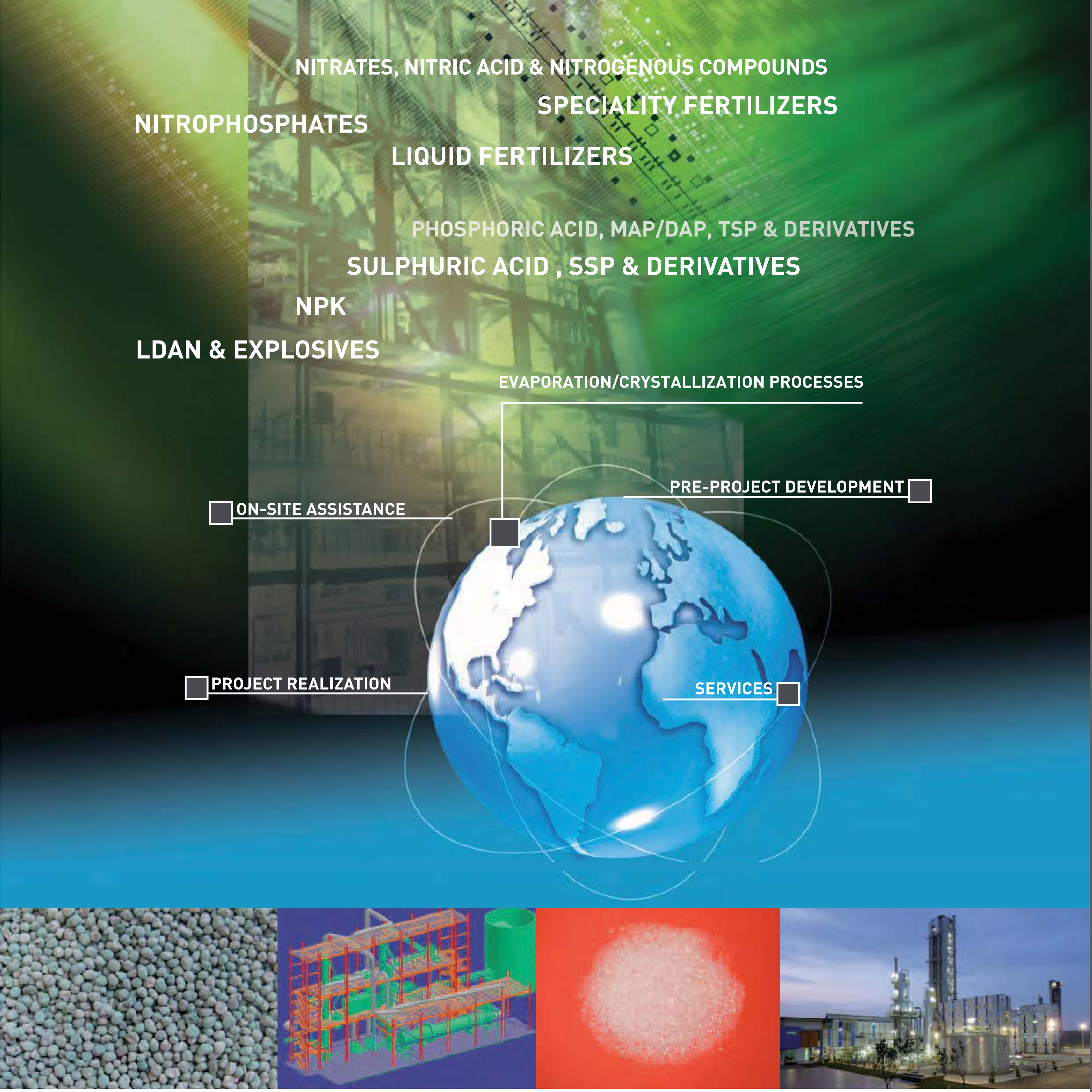

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# Nitrogen Industry News

## TANZANIA

### Consortium plans new large-scale fertilizer plant

An international consortium has announced its intention to develop a large-scale fertilizer complex at a site near Mtwara in the south of Tanzania. The consortium consists of technology supplier Haldor Topsoe A/S, project developer and EPC contractor Ferrostaal Industrial Projects GmbH, and Pakistani fertilizer producer Fauji Fertilizer Company Ltd, in partnership with the local state-owned Tanzania Petroleum Development Corporation. The project – currently the largest investment project in Tanzania – has an estimated investment cost of over $1 billion, and will produce 1.3 million t/a of urea, with upstream ammonia production based on new finds of natural gas in the country. The site is near existing port facilities, and the proposed landing point for offshore gas developments. At present the completion date is set for 2019-20. The urea will be destined for both the domestic and international markets, boosting Tanzania's agricultural industry, which represents one third of the country's GDP and employs more than 75% of the working population. The consortium emerged as the winner of a tender carried out by the Tanzanian government in 2013 and is currently in exclusive negotiations with gas suppliers regarding the supply of gas for the fertilizer complex.

Bjerne S. Clausen, Topsoe CEO, said: "We believe the plant will leave a positive footprint in Tanzania enabling the country to monetize its huge gas reserves and in the process create jobs and boost agricultural productivity. Ammonia is the primary ingredient in fertilizer and the plant will improve local supply significantly. From Topsoe's perspective the project is also extremely interesting. Not only does it represent a substantial contract value on its own terms, it also holds the potential of becoming a long term steady source of income due to our planned co-ownership of the plant." Topsoe will deliver license, engineering, hardware and catalysts for the fertilizer plant as well as taking a stake in its ownership.

The plant also appears to be the fruit's of Fauji Fertilizer Company's search for an offshore project where gas is more plentiful than at home in Pakistan, where the company has faced gas curtailments.

## UNITED STATES

### Koch expansion moving ahead

Koch Nitrogen Company, LLC has launched a new website, www.kfenid.com, to provide information on the $1.3 billion expansion of its Enid, Oklahoma fertilizer facility. The project will be implemented over a three-year period and will increase urea and ammonia production at the site by more than 1.0 million t/a. The website contains news about the project, employment numbers, contractor information, a supplier registration portal and a project timeline. Ground was broken on the new plant in October 2014, and last month local authorities approved rezoning requests for two parcels of land near Enid, Oklahoma, where new access road and rail spurs and turning areas will be built.

### CHS facing water shortage

Agricultural cooperative CHS Inc. is facing difficulties in securing a water supply for the company's planned $3 billion fertilizer plant at Spiritwood, North Dakota. The plant was announced last year, but so far has foundered on lack of an available water supply. The company was not able to get permits from the State Water Commission to use water from aquifers in the region, as many of the water rights for the area have already been allocated, and has now fallen back on a plan to build a pipeline to the Missouri River at Bismarck City, North Dakota, and pump water from there. The plant, which aims to produce 2,400 t/d of ammonia capacity with downstream urea, UAN and diesel exhaust fluid manufacture, will require an estimated 4-5,000 gallons/minute of water.

The current plan requires sharing the city's backup water intake via a treatment plant in the town, and local city commissioners have raised concerns that if anything were to happen to the city's main water intake, and the backup were required, there would be insufficient capacity for both Bismarck and CHS, probably requiring the company to agree to reduce its water intake during such outages.

### Solex to install urea cooler at Dakota Gasification

Elsewhere in North Dakota, Solex Thermal Solutions says that it has been selected to install a 50 ton-per-hour urea cooler and water temperature control module at the Dakota Gasification Company's Great Plains Synfuels plant. Solex uses a proprietary indirect plate heat exchange technology that cools the urea as it moves slowly through the unit. There is no air cooling, resulting in what Solex claim is a more efficient process, with lower power consumption, little or no emissions, and no product degradation.

"We are very pleased with this award which underscores Solex's strong experience and presence in the fertilizer market," Solex CEO Neville Jordison said in a press statement. "The compelling energy and environmental benefits of the products we offer today are a direct result of spending over a decade working closely with our customers to deeply understand their needs and the complex processes involved."

### Alaska looks to tax credits to restart Nikiski

Mike Chenault, speaker of the Alaska House of Representatives, has introduced a bill that would create a tax credit for nitrogen producers in the state. Chenault is the representative for Nikiski, where Agrium's ammonia-urea manufacturing site has lain idle since it was closed in 2007. The closure decision was due to a lack of suitably priced natural gas from the companies operating in the Cook Inlet, according to Agrium, and the proposed bill would give an Alaska-based ammonia or urea plant a credit equalling the state royalty paid by the plant's gas suppliers on their state leases, according to local press sources. Agrium has commented that the bill "will be a factor" in a decision on reopening the plant, and could offset engineering and permitting costs to resume plant operations.

### KBR awarded ammonia plant EPC contract

KBR has announced that it has executed an EPC contract with Yara International and BASF Group's new joint production company to license ammonia synthesis technology as well as provide engineering,

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procurement and construction (EPC) services for a world-scale ammonia plant to be constructed at BASF's site in Freeport, Texas. Upon completion, the ammonia plant will produce about 750,000 t/a of ammonia.

"KBR is proud to continue our relationship with Yara and BASF through our performance on this project," said Stuart Bradie, KBR President and CEO. "This project represents KBR's ability to bring world-class technology together with our engineering, procurement and construction skills to safely deliver complex energy projects in line with our strategy of differentiated EPC. This follows KBR's successful track record on the US Gulf Coast."

## PAKISTAN

### Engro looks abroad for new project

Following in the footsteps of Fauji Fertilizers, Pakistan's Engro Fertilizers Ltd says that it is also planning to develop new capacity outside Pakistan, in the Middle East and beyond, to offset problems in Pakistan caused by a continuing decline in domestic gas production and increasing shortages for fertilizer producers. Ruhail Mohammad, CEO of Engro Fertilizer, told local media that the company board has approved the concept of the new project, and that the company is now looking for suitable sites in Africa, the Middle East and United States, where gas is more readily available and hopefully at much lower prices than domestically. Existing fertilizer plants in Pakistan are not running on full capacity, and those on the SNGPL pipeline network have been forced to close as the country's gas shortfall has widened to more than 2 bcf/d. The government is looking towards liquefied natural gas imports as an alternate to the country's energy crisis, with the first shipments expected to reach the country in March. Pakistan has 7 million t/a of urea capacity, in excess of demand of 6 million t/a, but production languishes at 4.7 million t/a due to ongoing gas constraints.

## DENMARK

### New catalytic filter bag technology

Catalyst manufacturer Haldor Topsoe A/S has signed a cooperation agreement with equipment and services provider FLSmidth. The companies aim to commercialise a new catalytic filter bag technology, which is being branded as *EnviroTex*™. The technology, which has come out of four years of joint development by the two companies, is capable of removing dust, volatile organic compounds and nitrogen oxides in one integrated and cost-effective process. The key feature of the technology, for which a patent is pending, lies in three layers of filter fabric, each of which contains a tailored catalyst optimised for the removal of specific kinds of compounds from the off-gas that passes through it.

"The three layer structure is unique," explained Topsoe CEO Bjerne Clausen. "Not only because it provides us with the flexibility to tailor different catalytic combinations for different industries. It also makes it possible to handle the removal of several critical compounds in one integrated process. This can significantly reduce the cost of off-gas cleaning because today's standard is to use separate stand-alone systems to address removal of specific compounds. This translates into complexity and higher customer operating cost."

As part of the agreement between FLSmidth and Topsoe, the new product will be manufactured at FLSmidth's bag production facilities in Georgia USA. The filter bags will then be catalysed and assembled at Topsoe's catalyst production site in Houston, Texas. In fact Topsoe's production site will be expanded with an entirely new production line dedicated to the production of *EnviroTex* bags. The goal is to complete construction of this facility by end-2015.

## INDIA

### FACT re-starts due to lower gas prices

Fertilizers and Chemicals Travancore has been able to re-start its ammonia plant at Tracancore after a year's shutdown as the company received a new gas allocation from liquefied natural gas (LNG). The company stopped operations in January 2014 when delivered LNG prices reached $24.00/MMBtu. However, falling crude oil prices mean that FACT will now be able to source LNG at $10.90/MMBtu, excluding VAT (for which the state government has announced there will be a waiver) after an agreement brokered via state import and distribution company MMTC, one of India's main buyers of urea. The $10.90/MMBtu price is agreed up to April 21st this year, although there has been no news as to what will happen after that time.

### Chambal Fertilizers shuts down urea line at Kota

Chambal Fertilizers and Chemicals Ltd, part of the KK Birla group, says that it has shut down its number 2 urea plant at the Gadepan facility in Kota, Rajasthan, due to what the company calls the "unfavourable policy of the Government of India" as regards reimbursement for production beyond the listed 100% capacity of the plant for financial year 2014-15. Chambal says that it will use the shutdown period to carry out routine maintenance activities, and the plant will resume operation at the start of the new financial year, from April 1st 2015. Chambal has two urea fertiliser plants at Gadepan, with a total capacity of 2 million t/a.

State owned National Fertilizers' plant at Nangal was also shut down until April 1st after reaching 100% of the production it was allowed to be reimbursed for under the government's pricing policy

### Land allocated for new urea plant

Speaking at a local agricultural event, Chemicals and Fertilisers Minister Ananth Kumar said that land has been allocated for a new fertilizer plant in Karnataka with a capacity of 130,000 t/a of urea. The chief minister of Karnataka State, Siddaramaiah, has reportedly agreed to provide 500 acres for this purpose from state land. The State of Karnataka will also have 10% stake in the proposed project. The move comes only months after the closure of Mangalore Chemicals and Fertilizers, also based in Karnataka, because of its reliance on expensive naphtha for feedstock, and the new government's refusal to continue subsidising it, and two years after Zuari failed to get a 1.15 million t/a urea plant off the ground in the region precisely over the issue of land acquisition.

### Casale to revamp five plants for Iffco

Casale has signed a contract with the Indian Famers Fertilizer Cooperative (Iffco) for the revamp of five ammonia/urea plants at sites in Aonla, Phulpur and Kalol. The goal of the revamping project is to further reduce energy consumption at these plants by about 8% on average below current levels, which were themselves attained through past revamping projects. Casale says that a fully-integrated revamping approach will be used to guarantee that this goal will be achieved in the most efficient way, making use of Casale's specific know-how in both the ammonia and urea fields and its long-term experience of revamping any kind of process technology. Casale will provide the license for technical know-how, the basic engineering package, and technical site assistance. Casale will also supply proprietary equipment.

This project is a major step in making Indian fertilizer production more efficient, as the plants in question represent about 18% of India's total installed ammonia/urea capacity. Casale says that the main challenges of the project are the diversity of the original processes involved (Kellogg and Haldor Topsoe for the ammonia plants, and Snamprogetti and Stamicarbon for urea), each of which demands a dedicated approach, as well as the fast-track implementation schedule specified by Iffco, according to which the site works in all the plants will begin in 2016.

## BAHRAIN

### Topsoe in tie-up for DeNOx technology supply

Haldor Topsoe has signed a memorandum of understanding with local Bahraini firm Nass Industrial Services to offer turnkey solutions for local industrial companies for reducing emissions of nitrous oxides and volatile organic compounds (VOCs). Nass Group will work with Haldor Topsoe on the design and engineering of DeNOx systems and catalytic VOC combustion installations for the chemical, petrochemical and power plants across Bahrain, Saudi Arabia, Qatar, Kuwait and the UAE.

## QATAR

### Qafco partners GE for downstream services

GE Oil & Gas says that its downstream technology solutions business has been awarded a long-term service contract with Qatar Fertiliser Co. (Qafco) to help optimise the performance of the company's fertilizer plant in Mesaieed, Qatar. The agreement is between Qafco and GE's joint venture with Qatar Petroleum, Al-Shaheen GE Services Co. (QSC), and covers the standard maintenance and repairs of existing GE on-site power and compression equipment as well as training for Qafco workers and site operators. Mesaieed has a total capacity of 3.8 million t/a of ammonia and 5.6 million t/a of urea.

"A key priority for us is to optimize the long-term availability and efficiency of our Mesaieed plant's existing fertilizer production facilities," said Khalifa A Al Sowaidi, Qafco CEO. "Not only is GE Oil & Gas the original equipment manufacturer for the gas and steam turbines, centrifugal compressors and associated equipment, but it also has the proven local customer services capabilities we need to help us meet our production targets."

## RUSSIA

### Uralchem to increase capacity at Perm

Uralchem and Stamicarbon have agreed to partner to scale-up urea production at Perm Mineral Fertilizers in Russia, with an investment of around $63.7 million. The project is expected to increase urea production capability of the complex by 40% or 250,000 t/a by 2019. Under the deal, Maire Tecnimont-owned Stamicarbon will license its *Urea2000plus* production technology, as well as manage the project design and survey works. Russian urea technology firm JSC NIIK will be responsible for design documentation in compliance with Russian standards and regulations.

Uralchem's chief executive Dmitriy Konyaev said; "For Uralchem, a global player in the world fertiliser market, the increase of business efficiency is a strategic objective. The company's priority is to increase production at existing facilities via modernisation and introduction of the most advanced technologies."

Uralchem and Stamicarbon have previously worked together on developing urea synthesis technologies in partnership with Moscow State University.

### EZOCM looking to expand outside CIS

Following its participation in last year's ANNA (Ammonium Nitrate, Nitric Acid Producers Group) conference of nitrogen fertilizer producers, Ekaterinburg Non-ferrous Metals Processing Plant (EZOCM), Russia's largest producer of precious metal products, including catalyst gauze systems for nitric acid plants, is continuing its expansion to Western Europe and North America. Alexander Andreev, Deputy Director General for Commerce at EZOCM, said, "at ANNA 2014 we focused on promoting the development of our new catalyst gauzes that are already used successfully at some of the largest Russian and Eastern European nitric acid plants. Nitrogen fertilizer producers from the United States, from Europe, Asia and the Middle East have all showed interest in this product. I was encouraged that participants were pleased to learn more about our products and have an alternative to the more well-known gauze system suppliers. Companies understand that our country is the world leader in production of palladium and holds the second position after South Africa in production of platinum. Our access to reliable supplies of platinum and palladium provides our customers with the assurance of no delays in production schedules."

The EZOCM catalyst gauze offers new electrochemical activation techniques and lower platinum content that provide excellent conversion rates and lifetime. Catchment gauze packages can be configured with special palladium alloys for higher mechanical strength and immediate performance at start-up.

## SPAIN

### Nitric acid explosion causes vapour cloud over town

An explosion and fire at the Simar SA plant in Igualada, 65km west of Barcelona, produced an orange irritant vapour cloud of nitrogen oxides which hung over the town and led to residents being forced to remain indoors for several hours while firefighters tackled the blaze. Three workers were hurt in the explosion and six others were admitted to hospitals after complaining of breathing problems and eye irritation, authorities said. Simar manufactured ammonium nitrate, paraformaldehyde and methanol, according to the government, with nitric acid a key intermediate in the AN production. The explosion was said to have been caused by nitric acid coming into contact with a tank of iron sulphate, and the resultant explosion breached several other storage tanks containing phosphoric acid and formic acid. Two workers from the haulage company which was unloading the delivery of chemicals that exploded and an employee from the industrial estate suffered minor burns, although the latter victim was able to drive himself to hospital.

## SWEDEN

### Chemprojekt to build new nitric acid plant for Yara

Chemprojekt Nitrogen, now part of the Casale Group, has been awarded a contract by Yara's Swedish division to construct a new 685 t/d nitric acid plant at Köping. Chemprojekt will act as full EPC contractor and will rely on license and basic design furnished by Casale, via its

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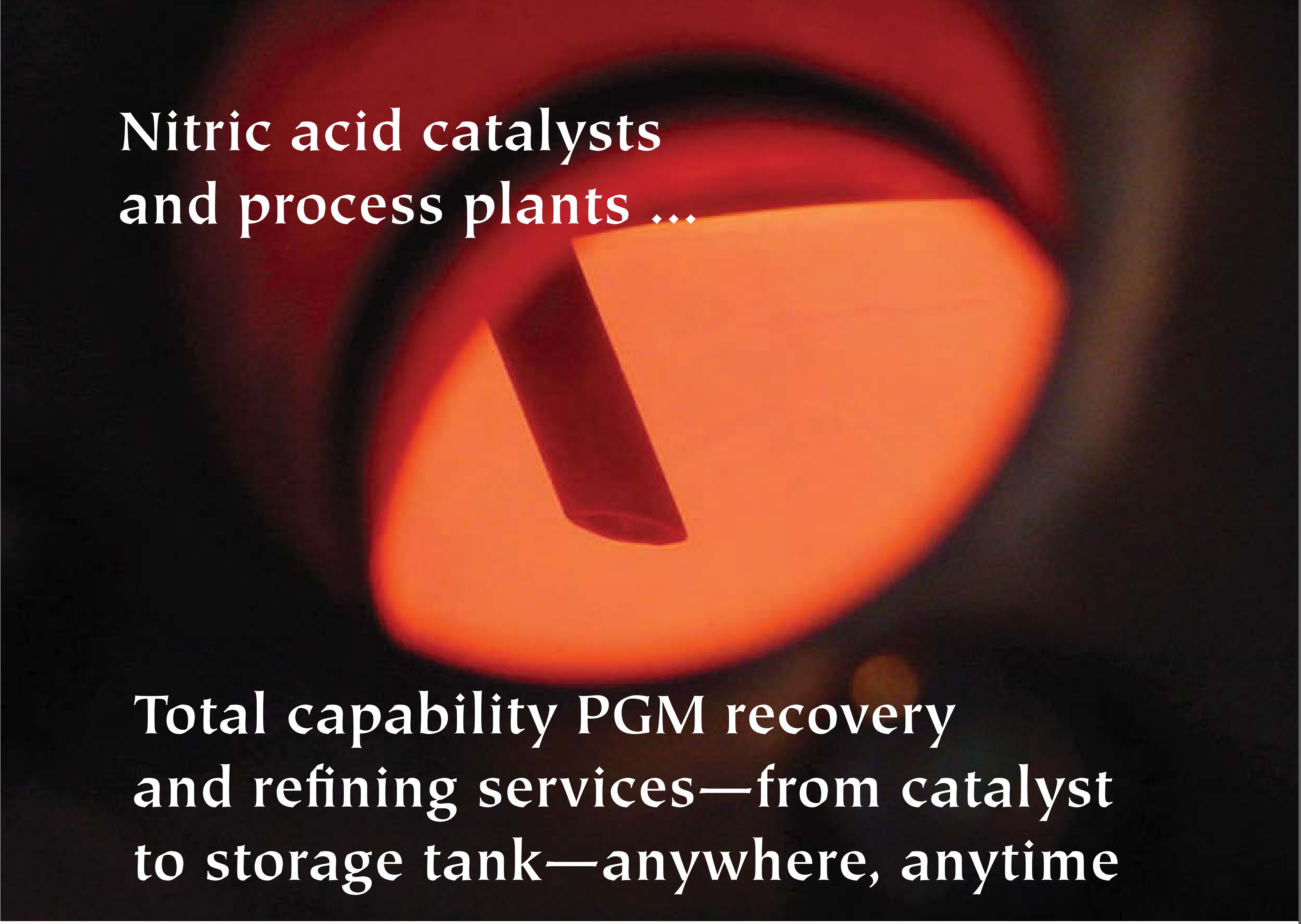

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recent acquisition from Borealis of GPN's nitrates and phosphate technology package. The contract will use state-of-the-art technology to improve energy efficiency and further reduce greenhouse gas emissions at the Köping site. Construction will start this year, with completion expected in the second half of 2017.

"We are very happy for the confidence shown by such a reputable and well known company as Yara in our capabilities and experience" said T. Plachy, CEO of Chemprojekt Nitrogen. Mr G. Guarino, CEO of Casale and Chairman of Chemprojekt, added: "this project is of particular relevance for Casale, as it comes right after last year's acquisition of the nitrates and phosphates technology package from Borealis, and marks the first project executed by Chemprojekt based on technology and know-how supplied by Casale after Casale Holding's recent acquisition of the control of the company."

## POLAND

### Grupa Azoty concerned about TTIP

Ahead of the European Parliament's public hearing on the potential impact on European chemical companies of the proposed TTIP agreement, Polish chemical company Grupa Azoty issued the following statement. Whilst we are broadly in favour of increased trade liberalisation between the European Union and the United States, we are concerned about the potential consequences of allowing American companies to enter European markets without first ensuring a fair and level playing field. The Group believes that the EU should oppose any reduction in tariffs affecting the chemical industry, or negotiate a transitional period during which US chemical companies would be subject to a number of EU regulations, including those on climate change. We believe that without these measures, European chemical companies will be at significant competitive disadvantage in transatlantic trade."

## HUNGARY

### TKIS to build new nitrogen plant

ThyssenKrupp Industrial Solutions (TKIS), the engineering and construction division of the ThyssenKrupp Group, and incorporating the old Uhde organisation, has won a follow-up order from Hungarian fertilizer manufacturer Nitrogénmüvek Zrt. to expand production capacity at the Pétfürdö site, 100km southwest of Budapest. TKIS will design and build a 1,150 t/d nitric acid plant. The contract value is "in the high double digit million euro region", according to TKIS. Completion is scheduled for 2017.

Nitrogénmüvek Zrt. already operates two ammonium nitrate plants supplied by TKIS at Pétfürdö. A plant to manufacture granulated calcium ammonium nitrate (CAN) and ammonium nitrate fertilizer is also under construction. ThyssenKrupp Industrial Solutions is responsible for engineering, procurement, construction, installation and commissioning of the new nitric acid plant.

Dr. Hans Christoph Atzpodien, CEO of ThyssenKrupp Industrial Solutions: "We are delighted at this third contract from Nitrogénmüvek Zrt. in only two years and at the greatly increased scope compared with the previous orders."

## SLOVAKIA

### New fertilizer plant in Slovakia

Haldor Topsoe A/S has signed contracts with Technip and Duslo s.a. of Slovakia over the design and construction of a new ammonia plant adjacent to an existing fertilizer complex in Šal'a, 65km from Bratislava. As part of the project, Haldor Topsoe will supply licensing and basic engineering as well as proprietary catalyst and equipment for the ammonia plant, while Technip has been awarded the EPC contract to develop EPC for the new plant. The plant is expected to go on-stream in early 2018 and will be designed to meet a daily production capacity of 1,600 t/d. The plant design will be based around Topsoe's proprietary Haldor Topsoe Exchange Reformer (HTER) technology, which the company claims ensures efficient and reliable conversion of feedstock, improving plant economics and minimising the environmental impact of the plant. HTER consists of a number of catalyst filled tubes installed in a refractory lined shell located in parallel with the main reformer and using the waste heat available from the secondary reformer. This allows a reduction in size of the primary reformer and its natural gas consumption, and minimises steam generation from the plant.

Per Bakkerud, Group Vice President of Topsoe's Chemical Business Unit noted that the project represents the first entirely new ammonia plant to be built in Europe over the last decades. "The ammonia industry is highly competitive and even the slightest changes in performance can impact the bottom line significantly. Improvements in production technology such as HTER are paving the way for improved production economics. This applies to new plants, but is also relevant when it comes to revamps of older plant facilities in Europe."

## TURKEY

### Stamicarbon launches new brand portfolio

Stamicarbon launched its new brand portfolio at the Nitrogen&Syngas conference in Istanbul in late February. According to the company, the purpose of the new brands are, in essence, to create clarity for the customers, showing the relation, structure and hierarchy of the company's offering and acting as a roadmap for future development. Stamicarbon's new brand architecture is built on the foundation of its well-known Full Life Cycle philosophy, but rather than branding each individual technology design, product and service, Stamicarbon offers its customer a total solution package, in every stage of a plant's journey. This total solution has become the basis of the new brands. These packages are referred to as LAUNCH™, ADVANCE™ and EVOLVE™. The branding strategy of Stamicarbon has thus moved from a product-oriented approach to a customer-oriented approach.

This three-stage Full Life Cycle approach entails the continuous support through the whole lifetime of the customer's urea plant, regardless of the stage the plant is at. LAUNCH™ means launching a reliable and profitable new urea plant, from project development, to process design, project management, training and start-up. ADVANCE™ means optimisation of production and improvement of product quality, hence advancing the plant operation. It allows urea producers to stay competitive with production improvements, monitoring and detection, staff training and full life cycle support. Finally, EVOLVE™ means upgrading a urea plant, guiding it to a next phase in its evolution. It allows urea producers to stay compliant and competitive with a range of safe, cost-effective and environmentally friendly revamp schemes. Within each of those packages, the specific products cater to the customers need. Examples of these are the ADVANCE™ CONSULT, a thorough plant assessment based on advanced plant modelling, or ADVANCE™ INSIGHT, providing real-time insight in the plant's key variables and EVOLVE™ OPTIMIZER, the solution launched on the conference in Istanbul to significantly increase a plant's capacity. ■

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STAMI UREA

A FULL LIFE-CYCLE PHILOSOPHY FOR SUSTAINABLE BUSINESS

Stamicarbon's engagement and commitment to urea plant owners doesn't stop after signing the contract and building the plant. Based on decades of experience in meeting the needs of a diverse range of customers, we have built up the insight and expertise to support you through the whole life cycle of your plant. Regardless of the stage your plant is at, we offer you reliable tailor-made technology solutions, products and services that match your needs and increase production in a sustainable way. With three proven solutions, LAUNCH™, ADVANCE™ and EVOLVE™, we can address all your questions and requests.

**For more information contact Stamicarbon B.V., The Netherlands, visit www.stamicarbon.com or email communication@stamicarbon.com**

LAUNCH™
**Creating your plant**
Launch a new plant with all technologies, products and services needed for successful, sustainable and profitable urea production.

ADVANCE™
**Optimizing your plant**
Advance your plant performance with products and services to support and train plant staff and improve equipment and product quality to stay competitive.

EVOLVE™
**Upgrading your plant**
Evolve your plant to the next level with revamp and debottlenecking to increase production capacity and reduce energy consumption and emissions.

The innovation & license company
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UNITED STATES

## Methanex starts up first Geismar plant

Methanex has begun production at its Geismar 1 unit, relocated from Chile, where the company was forced to idle the plant due to gas shortages. The 1.0 million t/a methanol train will be the first of two relocations from Punta Arenas on the southern tip of Chile, allowing Methanex to take advantage of cheap shale gas. Company president and CEO John Floren said that the plant will ramp up to full production over the next few weeks, making it the largest operational methanol plant in the US, where there are six other plants operating with a capacity of 2.4 million t/a, and plans for several more.

"The Geismar 1 plant was completed over roughly a two and a half year period," Floren said. "Our estimated total cost for the completion of the two Geismar plants remains approximately $1.4 billon. We believe this represents a substantial schedule and cost savings relative to a new-build plant."

The Geismar 2 facility, which also has a capacity of 1m tonnes/day, is on schedule to begin methanol production in the first quarter of 2016.

### Air Liquide to build $O_2$ plant for Yuhang

Air Liquide says that it has been selected to supply oxygen for a $1.85 billion methanol plant to be built in St. James Parish, Louisiana.Air Liquide will provide Chinese petrochemical company Yuhuang Chemical Inc. with 2,400 t/d of oxygen via a new energy efficient air separation unit to produce oxygen, nitrogen and argon for use in manufacturing. The infrastructure will connect to the company's Louisiana's pipeline system and is expected to be commissioned by 2017. Air Liquide will invest $170 million in the project.

The Yuhuang complex on the Mississippi River in St. James Parish will be one of the largest of its kind in the US, and is expected to produce around 5,000 t./d of methanol. Construction on the complex will begin in 2016, with the first phase of the methanol plant beginning operations by 2018. The company's goal is to reach a capacity of 3 million metric tons per year by addition of a second train. Yuhuang is the brainchild of Chinese tycoon and politician Wang Jinshu, and has secured 1,100 acres for the site. The project is currently at the permit stage, and is awaiting an environmental impact assessment from the Louisiana Department of Environmental Quality, due in March.

### Methanol expansion project under way

OCI Beaumont has begun a $250 million debottlenecking project which will increase output by 25%, to 912,500 t/a of methanol and 305,000 t/a of ammonia at its site in Texas. At the same time, site preparation work has begun on a 500 acre site next to the existing methanol plant as part of a 30 month construction project for OCI subsidiary Natgasoline Methanol, which is building a 1.7 million t/a methanol plant that is eventually aimed to be integrated into downstream methanol to gasoline production.

### Sasol abandons GTL project

Sasol Ltd. Says that it has decided to shelve its $11 billion proposed gas to liquids (GTL) project at Lake Charles on Louisiana's Gulf Coast, because of the plunge in world oil prices. An $8 billion ethylene project at the same site is still to proceed, however. When Sasol said it was thinking of building a GTL plant in Louisiana in 2012, a barrel of oil was worth around 40 times as much as 1 MMBtu of natural gas; today the ratio trades at about 17. Sasol said that ratio must be at least 16 for the project to make economic sense.

### End of line for coal gasification plant

The US Department of Energy says that it will no longer support FutureGen Industrial Alliance, a public-private partnership aiming to build a coal gasification plant in Illinois which planned to capture the carbon and pump it to underground storage. The project, part of the Bush 'clean coal' initiative, was supposed to demonstrate the feasibility of a new, climate-friendly way to use coal, but cheap gas, reluctant power buyers and wary investors have killed the project. FutureGen was relying on up to $1.1 billion of federal money, and had been championed by both the Obama administration and Illinois Senator Richard Durbin, but the DoE says that FutureGen's sponsors could not meet the September deadline to get the project's plans finalised. Another gasification plant, Hydrogen Energy California faces a similar make or break deadline.

Other coal gasification/carbon capture projects in the US have a similarly troubled history, including NRG Energy Inc. in Houston, Southern Co.'s Kemper plant in Mississippi, and Summit Power Group in Texas.

### Bimoass to urea plant proposal

Florida-based BioNitrogen Holdings Corp. is seeking planning permission to build a $330 million urea fertilizer plant at the Riverview Industrial Park in Pennsylvania. BioNitrogen uses patented technology to gasify solid waste agricultural biomass into syngas, which is then processed to ammonia and urea fertilizer. BioNitrogen is still in discussions with the Reading Redevelopment Authority which owns the 50-acre site over a memorandum of understanding, with the RRA apparently concerned about BioNitrogen's plan to finance the development.

BioNitrogen is also working to develop two similar $300 million projects in Florida, aiming to break ground later in the year, to convert tree trimmings into urea, one in Taylor County, Florida and the other in Hendry County, Florida. Each BioNitrogen plant will be designed to produce 180,000 t/a of urea fertilizer.

SAUDI ARABIA

## Methanol Chemicals rethinks formaldehyde plant

Methanol Chemicals Co (Chemanol) will repeat a feasibility study on a planned 60,000 tonnes/year sulphonated naphthalene formaldehyde plant in Saudi Arabia in view of recent market developments, according to a company statement. The $20 million project had received approval from the company's board in December 2012.

"Due to the recent changes and developments in the market, the company hereby announces that the [Chemanol] board of Directors has directed the management… to reconduct the feasibility study of the project in accordance with the market information and the company strategy, Chemanol said in a filing to the Saudi Stock Exchange. "Further developments in this regard will be announced in due course," it said. The company is also exploring new investments in specialty chemicals and petrochemicals, including the acquisition of advanced technologies inside and outside Saudi Arabia, it said.

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## ICELAND

### Renewable methanol plant to triple production

Carbon Recycling's 1,300 t/a renewable methanol plant at Svartsengi in southwest Iceland will triple its production to 4,000 t/a in a few weeks, following approval from the Icelandic National Planning Agency. The plant uses geothermal electricity too produce hydrogen via electrolysis, and takes advantage of carbon dioxide emissions from the on-site HS Orka geothermal power plant to produce methanol, which is used for producing biodiesel and as an additive to gasoline.

"So far we've been able to produce 1,300 tons per year. Now we have improved the production capacity so that it has tripled and in a few weeks we will start a new plant," said managing director of business development at Carbon Recycling Benedikt Stefánsson. The company has the potential to build another plant alongside the current one, which could produce 40,000 t/a of methanol.

## QATAR

### Qatar launches $CO_2$ recovery project

Qatar Fuel Additives (Qafac) has officially launched an $80 million $CO_2$ recovery project at its methanol plant at Mesaieed. The project will capture 500 t/d of carbon dioxide from the methanol plant's exhaust stack and re-route it back into the process in order to boost methanol capacity. The official launch was conducted in the presence of Minister of Energy and Industry Dr Mohamed bin Saleh al-Sada; Minister of Environment Ahmed Amer Mohamed al-Humaidi and other dignitaries.

"The harsh reality is that the environment is facing severe degradation. The climate is changing as a result of high greenhouse gas emissions and this threatens the wellbeing of the environment and the future generation. Hence, it is critical that organisations, big and small, put sustainability at the forefront of their agenda," Qafac chairman Hamad Rashid al-Mohannadi said at the event.

"After conducting a thorough feasibility study to examine the technical and economical benefits of the project, a cost analysis showed the project had definitely helped increase our production and profit," added Qafac CEO Nasser Jeham al-Kuwari.

The recovery unit has been constructed under licence from Mitsubishi Heavy Industries (MHI), and comprises flue gas pre-treatment, carbon dioxide absorption, solvent generation and carbon dioxide compression. The plant will be one of the world's largest commercial-scale carbon dioxide capture facilities.

## UNITED ARAB EMIRATES

### Dubai to run municipal vehicles on waste oil biodiesel

Dubai has signed an agreement with Neutral Fuels LLC to run municipal vehicles on biodiesel made locally from 100% waste cooking oil. Neutral Fuels has had a plant manufacturing biodiesel in the UAE since 2010, when it was the first biodiesel manufacturer licensed in Dubai. Waste oil biodiesel results in an 80% reduction of the life cycle carbon footprint relative to regular diesel. It also reduces carbon monoxide emissions by 40% and smog emissions by 50%.

Hussain Lootah, Director General of Dubai Municipality, said, "Dubai will be one of the world's most sustainable cities by 2020, when the city hosts the World Expo. Our biodiesel initiative is a huge leap towards achieving this. We are pleased to take this next step with Neutral Fuels as they share our vision and have provided a solution that meets the needs of our growing city."

## CANADA

### Investment decision by year end on MTG plant

Blue Fuel Energy says that it will make a final decision on a $2.5 billion methanol to gasoline (MTG) plant to be build in northern British Columbia by the end of 2015. CEO Juergen Puetter told Canadian press that the company expects to have its engineering work done, plant designs complete and permitting in place by the end of this year in order to make a final investment decision on the plant near Chetwynd. Puttner is also CEO of the Canadian Methanol Corporation, and the board includes two former Methanex executives. He says that he is convinced that local natural gas could feed a world-scale methanol plant and a downstream 1 billion litre/year methanol to gasoline unit, providing up to 20% of British Columbia's gasoline supply. The plant is in the permitting stage with the provincial government, and Blue Fuel is working with the BC Oil and Gas Commission, Agricultural Lands Commission, Canadian National Rail and the District of Chetwynd.

## JAPAN

### Hydrogen fuel push for Olympics

The Japanese government says that it is planning to spend $385 million on hydrogen fuel infrastructure ahead of the 2020 Olympic Games in Tokyo. The money will be used to construct 35 hydrogen fuelling stations in and around Tokyo. The government also wants Toyota and Honda to have at least 6,000 hydrogen powered fuel cell vehicles on the road in Japan by then. The Tokyo city government is paying 80% of the cost. Businesses that build hydrogen refuelling stations will pay a maximum of $850,000 per location. Anything over that will be paid by the government. The City of Tokyo will give buyers of hydrogen cars an $8,500 tax credit on top of the $17,000 credit already available from the national government. Japanese Prime Minister Shinzo Abe has called for more aggressive promotion of fuel cells and the construction of a national hydrogen fuelling station network.

## SWEDEN

### Linde to build hydrogen fuel station

Linde Group is to build Sweden's first hydrogen refuelling station at Arlanda airport, just outside Stockholm, to coincide with the introduction of hydrogen fuel cell vehicles by several leading auto manufacturers. The hydrogen will be produced by electrolysers running on renewable electricity from hydropower in AGA's new production plant in Sandviken, 180km north of Stockholm.

"We are convinced that hydrogen-fuelled zero-emission vehicles with a range of more than 500km between refuellings will be an important factor in reaching Sweden's goal of fossil-free transportation by 2030," said Roger Andersson, responsible for development at AGA, Clean Energy.

## INDIA

### Jindal Steel will attempt to do more coal-to-gas plants in future

Jindal Steel and Power Ltd (JSPL) which has commissioned India's first coal-to-gas plant in Angul in Odisha today announced that it will look at more such plants if it is assured of coal supply.

Speaking on the sidelines of a seminar on gasification, Ravi Uppal, CEO and MD of Jindal Steel said that the coal gasification technology used at the plant uses natural coal. JSPL has signed an agreement with Lurgi Technology Company, South Africa, for

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providing the technology for coal gasification. "We took the challenge of using natural coal," said Uppal, further adding that the NDA government should focus on producing gas using local coal to meet the gas shortage. "We consume 48 billion cubic metres of gas annually and we have a deficit of 30 billion cubic metres. We meet this deficit by importing liquefied natural gas which is expensive," he said.

The gas produced at the plant is used for captive consumption at its 1.5 million-tonnes-per-annum steel mill in Angul. "Our plant consumes 80 percent of the gas produced," said Uppal. Jindal Steel is looking at other uses for the remaining gas. "We can look at converting gas into diesel or methanol or supply it to fertilser plants that can produce ammonia or urea with it," he said.

Jindal Steel has also spent Rs 3,000 crore on the plant which produces 225,000 cubic metres per hour of gas. The plant is operating at a 50 percent capacity. The company will look at more such gasification plants once the Angul plant runs at an increased capacity. The coal for the gasification plant is being sourced from the Utkal B 1 coal block in Odisha. "If we are assured of regular coal supply, we will put up more gasification plants," said Uppal.

On the Delhi High Court's recent decision to halt the auction of two mines (Utkal B1 coal block in Odisha and Gare Palma IV/6 in Chhattisgarh) of Jindal Steel, Uppal said that the government could have avoided this mess had it not changed the end use of the mines from steel to power. "Nobody can undermine the importance of the steel sector. There was no reason to change the end use to power," he noted.

## EGYPT

### MoU signed for formaldehyde plant

Kuwait and Egypt have signed a memorandum of understanding for the production of a 70,000 t/a formaldehyde plant in the country, with a price tag put at $100 million. The plant will also consume around 30,000 t/a of methanol and urea. It is one of $6.8 billion of joint Egyptian and Kuwaiti developments set to be announced at the Egypt Economic Development Conference in March as part of a list of projects offered by the Egyptian petroleum sector.

## CHINA

### Contracts for SNG expansion

The China National Offshore Oil Corporation (CNOOC) has awarded a contract to Porvair Filtration Group Ltd. to provide filtering equipment for a coal-to-substitute natural gas (SNG) gasification plant to be built at its 12 million t/a Huizhou refinery in Guangdong Province, China. Porvair will supply the plant char filtration equipment, which will be used in areas downstream of the gasifier and heat exchanger to remove erosive and abrasive char particulates contained in syngas that has been produced from coal gasification before they can reach and potentially damage other downstream equipment and processes. The company will deliver its scope of work under the contract to support the plant's scheduled start-up in 2016.

Shenzhenshi Qianhai Zitong Clean Energy Co. Ltd., has also entered an agreement with CNOOC to establish a joint venture for the investment, construction, and operation of a partial oxidation (POX) coal-to-hydrogen plant as part of CNOOC's second phase refinery integration and expansion project at Huizhou. The POX coal-to-hydrogen plant will use coal and oxygen as feedstock to produce 150,000 t/a of hydrogen for use in the refinery as well as at a planned ethylene plant included in the Huizhou integration and expansion project. The plant will require a 1.64 million t/a feedstock supply of coal, will consist of nine units, including coal storage and transportation, air separation, coal preparation, gasification, transformation, low-temperature methanol washing, pressure swing adsorption, sulphur recovery, and sour-water stripping.

### SinoCoking to sell hydrogen to Shenma

SinoCoking Coal and Coke Chemical Industries, Inc. has signed an agreement to provide hydrogen to Henan Province-based Shenma Industry Co Ltd. Hydrogen production is scheduled to begin later this year and will be generated at a facility located alongside SinoCoking's current syngas facilities. The hydrogen will be purified by SinoCoking to meet Shenma's requirements, in excess of 99.96% purity, a production quantity of 12,000 $m^3$/h. SinoCoking expects the new hydrogen plant to be completed in October 2015 at a cost of $11 million. The company previously announced that current production of 25,000 $m^3$/h of syngas at its facility is expected to double. However, the company's longer-term plan is to produce hydrogen "on a much larger scale" from its underground coal gasification ("UCG") syngas project currently under development and scheduled to begin operations, along with the second aboveground facility, by the end of March 2015. The testing period for the underground facility should be completed during the month of April.

SinoCoking expects that hydrogen to be produced at its above ground and underground syngas facilities will be used in hydrogen fuel cells and supplied to regional hydrogen refuelling stations supported by the Chinese government through its China 2014-2020 Energy Development Plan. ■

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# People

Two students from Sultan Qaboos University (SQU) have been named joint winners of the annual Honeywell UniSim Design Student Challenge for the Europe, Middle East, Africa (EMEA) region, according to Honeywell Process Solutions. **Ahmed Abdullah Al Maimani** and **Mohammed Nasr Al Kindi**, both engineering students at Sultan Qaboos University in Muscat, Oman, showcased their winning submission to more than 1,000 attendees at the 2014 Honeywell Users Group EMEA at The Hague, in the Netherlands.

The research paper by Al Maimani and Al Kindi investigated ways to reduce energy consumption during the production of syngas from natural gas. Titled 'Production of Synthetic Methane, Hydrogen and Carbon Dioxide By-products from Ammonia Plants', it concluded that it is possible to produce synthetic methane from these by-products and recycle it back into the plant in order to reduce the amount of natural gas required for certain production levels.

**Chandrapal Singh Yadav** has been elected as the new chairman of urea cooperative Krishak Bharati Cooperative (Kribhco). Yadav, who was previously vice chairman of Kribhaco, will replace outgoing chairman Vaghjibhai Rugnathbhai Patel. Patel, who has chaired cooperative since his election in 2010, will now in turn become vice-chairman of the cooperative. Kribcho said that the election of Yadav by the board of the cooperative was unanimous in a statement released to the press. Yadav is also a member of the 250-seat Rajya Sabha, the upper house of the Indian parliament.

Coromandel International says that its managing director **Kapil Mehan** has resigned due to "personal reasons". In a filing to the Bombay Stock Exchange the company said that the board has accepted his resignation, which became effective from February 13th. The filing said that the company's vice chairman **V Ravichandran** would take temporary charge of the company. Mehan joined Coromandel in 2010 and had previously served as an executive director of Tata Chemicals.

*Nitrogen+Syngas's* sister title *Fertilizer International* has a new Editor. **Mark Evans**, the long-standing editor of F.I., is retiring at the age of 65, after a record breaking 27 years as editor of the title, and fully 30 years of journalism within the fertilizer industry, for British Sulphur Publishing, then CRU, who bought British Sulphur in 1994, and of course since January 2007 as a partner in BCInsight Ltd. Mark's replacement is **Simon Inglethorpe**, who has joined BCInsight Ltd. from Haymarket Media Group, where he was Business Editor at The ENDS Report, the UK's leading publication for environmental professionals. A graduate in geology from Kings College London, Simon spent a long career as a mineral resource scientist with the British Geological Survey, a role that involved extensive international project work in Africa, Asia, Central America and Europe.

Simon says that he looks forward to taking the helm of Fertilizer International. "It is a great pleasure to be taking over from the estimable Mark Evans," he said. "My background in the earth sciences means I do recognise the underlying importance of mineral resources to the sector, particularly phosphates, potash and mineral processing – as well as the rise of shale gas. But there is much more to the fertilizer industry than resources and my experience in business journalism should serve me well as I immerse myself in technology, products, markets and finance.

**DeLome Fair** has joined the SES executive team as Senior Vice President, Gasification Technology. Her 25-year career in gasification spans leadership positions with GE Energy and Chevron/Texaco. Prior to joining SES, Ms. Fair led GE Energy's global team of 135 engineers in the U.S., India and China, as General Manager, Gasification & Process Systems Technology. In that post, she was responsible for engineering to GE's global gasification business, including business development support.

## Diary 2015

### MARCH

23-26

IFA Global Safety Summit, VANCOUVER, Canada. Contact: IFA Conference Service,
28 rue Marbeuf, 75008 Paris, France
Tel: +33 1 53 93 05 00
Email: ifa@fertilizer.org

30-31

6th Methanol & Emerging Derivatives Conference, LIANYUNGANG, Jaingsu, China. Contact: Karen Zhang, ASIACHEM
Tel: +86 21 50329699-126
Fax: +86-21-51686603
Email: karen@chemweekly.com

### APRIL

20-22

SynGas 2015, TULSA, Oklahoma, USA.
Contact: SynGas Association
Web: www.syngasassociation.com

### MAY

25-27

83rd IFA Annual Conference,
ISTANBUL, Turkey
Contact: IFA Conference Service,
28 rue Marbeuf, 75008 Paris, France
Tel: +33 1 53 93 05 00
Email: ifa@fertilizer.org

### JUNE

7-10

International Methanol Technology Operators' Forum, LONDON, UK
Contact: Johnson Matthey
Tel: +44 (0) 1642 553601
Email: imtof@matthey.com

11-12

26th IMPCA European Mini-Conference, Europe. Contact: IMPCA,
Avenue de Tervueren 270 Tervurenlaan,
1150 Brussels, Belgium
Tel: +32 (0) 2 741 86 83
Fax: +32 (0) 2 741 86 84
Email: info@impca.be

22-26

IFDC/IFA Nitrogen Fertilizer Production Technology Workshop, VIENNA, Austria
Contact: IFDC, P.O. Box 2040,
Muscle Shoals, Alabama 35662, USA
Tel: +1 256 381 6600
E-Mail: training@ifdc.org

### SEPTEMBER

AIChE Ammonia Safety Symposium,
BOSTON, Massachussets, USA
Contact: AIChE Customer Service
Tel: +1 800 242 4363/+1 212 591 8100
Fax: +1 212 591 8888
Email: xpress@aiche.org

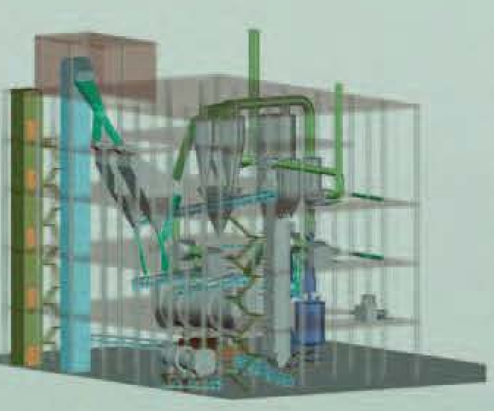
21-23

IFA Production and International Trade Conference, Florida, USA. Contact: IFA Conference Service, 28 rue Marbeuf,
75008 Paris, France. Tel: +33 1 53 93 05 00
Email: ifa@fertilizer.org

### OCTOBER

4-9

Ammonium Nitrate/Nitric Acid Conference,
JASPER, Canada. Contact: Agrium



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# Plant Manager+

## Problem No. 29 Stripper versus decomposer: What is the difference?

**In 1967, Mr Piet Kaasenbrood (picture left) of Stamicarbon invented the $CO_2$ stripper. The $CO_2$ stripper revolutionised the urea process industry as it reduced the synthesis pressure from about 200 bar to 140 bar and reduced the energy consumption of a urea plant by about 50%. The $CO_2$ stripper decomposes the unconverted ammonium carbamate coming from the reactor at the same pressure as that in the reactor. Therefore no water needs to be added to recycle this carbamate to the reactor, which is beneficial for the conversion in the reactor.**

**The phase diagram of the system $NH_3$-$CO_2$-Urea-$H_2O$ (see picture) shows that by stripping with $CO_2$ one is able to significantly reduce the ammonia content in the reactor outlet while at the same time reducing the temperature. Minimum temperatures are vital to keep corrosion rates under control and to allow economical materials of construction to be used. A decomposer on the other hand only removes the excess ammonia from the reactor solution until the azeotropic composition is reached. During this process the temperature increases. It is for this reason that in a $CO_2$ stripper with a bottom temperature of 170-175°C 25-22-2 stainless steel can be used, while in a Saipem stripper, with a bottom temperature of 204-212°C, titanium or zirconium needs to be applied to handle the high temperature.**

**Mr Kessla Belkacem of AOA in Algeria initiates the Round Table discussion:** I have a question: I would like to know what the difference is between decomposing and stripping?

**Mr Mark Brouwer of UreaKnowHow.com in the Netherlands replies:** These terms are frequently mixed up. Theoretically, stripping is decomposing with the help of a stripping gas. So a $CO_2$ stripper works with $CO_2$ as a stripping agent and is a stripper. An $NH_3$ stripper is in my view more a decomposer than a stripper although one could argue that the decomposed carbamate acts as a kind of stripping agent.

**Mr Malik Sohail of SAFCO in Saudi Arabia gives his view:** Actually the purpose of both the stripper and decomposer is the same, the decomposition of ammonium carbamate. If this decomposition takes place mainly by partial pressure motive then it is called stripping and if this motive is heat then it is called decomposing.

**Mr Nawal Gupta of KRIBHCO in India contributes to the discussion:** If ammonium carbamate is dissociated into $NH_3$ and $CO_2$ gases by reducing the pressure of the solution, it is called decomposition. If the same is achieved by reducing the partial pressure of one of the components (that of $NH_3$ in the case of $CO_2$ stripping or that of $CO_2$ in the case of $NH_3$ stripping), it is called stripping.

**Mr Kashif Naseem of SABIC in Saudi Arabia provides his view:** Decomposition: Carbamate is formed in the reactor and passes to the stripper. With heat of steam this reaction is reverted back to ammonia and $CO_2$ with breakage of its bond.

Stripping: The formed ammonia and free ammonia are forced to come out using $CO_2$ as the stripping agent.

**Mr Thota Raju of Nagarjuna Fertilizers and Chemicals Ltd. in India adds to the discussion:** In my view we normally heat the carbamate solution to reverse the reaction towards the reactant side (i.e. $NH_3$ and $CO_2$). The $NH_3$ and $CO_2$ will be in the liquid phase and in order for them to go to the gas phase their saturation pressure at those conditions should be greater than partial pressure of the respective in gas phase. In a stripper the gas phase pressure is high so suppose that in a Saipem process the excess ammonia and formed ammonia is present in a higher quantity (i.e. high mole fraction) than as per the vapour liquid equilibrium, it will start vaporising. It first increases its partial pressure in the gas phase and since the system pressure is constant it decreases the $CO_2$ partial pressure then stripping starts.

**Mr Azad Panchal of GNFC in India asks a similar question:** In the Saipem urea plant the stripper has the same function as the MP decomposer, why is one called a stripper and the other a decomposer?

**Mr Nimesh Maurya of KRIBHCO in India replies:** In the HP stripper the decomposition is carried out by stripping action using Henry's law in the presence of excess ammonia while in the medium pressure decomposer decomposition is carried out by elevated temperature at reduced pressure only. There is not any stripping action.

**Azad comments:** But the stripper is also operating at high temperature by using medium pressure steam and at a reduced pressure of 145 kg/cm$^2$, while the reactor operates at 160 kg/cm$^2$.

**Nimesh replies:** In the HP stripper part of the ammonium carbamate is decomposed due to elevated temperature, but the decomposition is mainly achieved by stripping action so it is called a stripper.

**Mr Shashank Sharma of Tata Chemicals Ltd. contributes:** In the stripper, 80% of the ammonium carbamate is decomposed into $NH_3$ and $CO_2$ by the stripping action of $NH_3$ vapours occurring due to Henry's law as the $NH_3$ is present in excess. Since the main action here is decomposition by stripping it is called stripper. In the MP decomposer the decomposition takes place due to flashing and the increase in temperature of the ammonium carbamate solution in the medium pressure section, as a result of which it is decomposed into $NH_3$ and $CO_2$.

**Mr Prem Baboo of NFL in India gives a detailed reply:** Definition of a stripper: To reduce the partial pressure of the product by swamping the system with one of the reactants, which considerably reduces the partial pressure of the other reactant without changing the total pressure. Either $CO_2$, $NH_3$ or both can be used as a stripping agent.

Definition of a decomposer: The process based on the first principal of decrease in pressure and increase in temperature followed by a series of decomposition stages where the reactor discharge is treated successively at lower pressure.

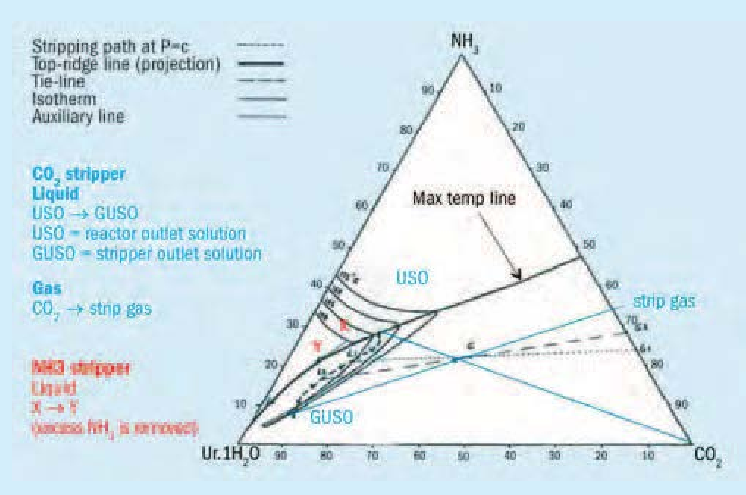
The delta P for a decomposer is greater than for a stripper. There is no delta P between the reactor and the stripper, however in a Saipem process there is small delta P.

With the decomposer the solution flashes due to the large difference of pressure and with the stripper the base is Henry's law of partial pressure and mass transfer is also involved.

Decomposition is based only on high temperature and low pressure, decomposition occurs due to let down, the water recycle is greater. Stripping is based on the partial pressure. In the Stamicarbon process $CO_2$ is introduced in the stripper, which is advantageous because $CO_2$ increases P1 $CO_2$ to P2 $CO_2$, so P1 $NH_3$ will be reduced to P2 $NH_3$ to maintain constant total pressure as $PCO_2$+$PNH_3$=Total Pressure. Now $K\text{-}1 = (X^2_{NH3}\ X\ X_{CO2})\ /\ X_{Carb}$. at particular temp K1 is constant so when $X_{NH3}$ is reduced to keep K1 constant X Carbamate will be reduced much faster by decomposition as $X_{NH3}$ appears in the equation with power of 2.

Decomposition is favoured by low pressure but energy is required to recycle the decomposition products back to the reactor. Also, at low pressure more water is evaporated during decomposition and this water will enter the urea reactor along with the recycle stream and adversely affect the conversion. Thus if the decomposition is carried out in a single stage near atmospheric pressure the carbamate formed during recovery at the same pressure will carry a lot of water. Considering these factors, decomposition is carried out in a number of stages.

Fig 1: $NH_3$-$CO_2$-urea-$H_2O$ phase diagram



In a stripping process the first stage decomposition and recovery is done at the reactor pressure which permits heat to be recovered at high pressure and also results in energy saving the for returning the recycle streams to the reactor. However, in the Saipem process there is a difference in pressure between the reactor and stripper, so there is the additional advantage of differential decomposition.

**Mark adds to Prem's explanation:** The phase diagram above helps to explain the difference between the $CO_2$ stripper and $NH_3$ stripper (or HP decomposer). ■

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# The Chinese ammonia industry

Cai Zeng of Clariant reviews the ammonia industry in China, with a focus on the technical challenges for both natural gas and coal-based ammonia plants.

China is the world's largest ammonia consumer and producer. With over 80 million t/a of ammonia production capacity, China has almost 40% of the global total. The development of the ammonia industry played a key role in China being able to feed around 20% of the world's population with only around 8% of the arable land in the world. In order to meet increasing living standards and continued economic development, the ammonia industry is and will continue to be strategically important for China's 1.35 billion people, especially in terms of food security. Significant efforts and resources were devoted to the development of the ammonia industry over the past several decades. This article aims to review the historical development, current landscape, new regulations and outlook of the ammonia industry. Innovation in ammonia synthesis catalyst development, the vast experience and lessons learned from coal-based ammonia plants are beneficial to the world ammonia industry and will be also reviewed.

## Historical development

The Chinese ammonia industry began in 1930's and the first ammonia plant of 39 t/d capacity was constructed in Nanjing in 1934. On February 5th 1937, the ammonia plant successfully produced the first batch of ammonium sulphate. By 1949, there were still only two ammonia plants, in Nanjing and Dalian respectively, and the total capacity was only 45,000 t/a.

As an agricultural country, China had a strong demand for fertilizer. and hence over 2,000 small ammonia units were subsequently built in the 1950's[1]. Nearly all of these plants used fixed bed gasification technology, and the end product was ammonium bicarbonate. These plants were of small scale, with a typical capacity ranging from 800-10,000 t/a. Due to the poor infrastructure at that time, these plants were widely distributed over the country, which facilitated fertilizer distribution. However, beside their small capacity, those plants were relatively inefficient and had high pollution rates. Therefore, many of these small ammonia units were gradually phased out over time. During the 1970's, China was able to import state-of-the art ammonia technology and started to build ammonia plants with a capacity of 1,000 t/d for urea production. Among the 13 large ammonia plants with licensed technology, ten plants, including 8 licensed by Kellogg/KBR, used natural gas as feedstock. China has abundant coal resources and limited natural gas and oil reserves. Due to rising oil prices and the successful commercialisation of entrained flow coal gasification technology in the 1980's, all naphtha-fed ammonia plants and several natural gas-fed plants became less competitive in economic terms, and were retrofitted to coal-based ammonia plants. The successful commissioning of these large and high efficiency ammonia plants laid a solid foundation for the continued growth of the ammonia industry in the country.

With the growing demand of ammonia and fertilizer, many more large ammonia plants have been built since the 1990's. Ammonia production capacity had reached 80 million t/a in 2013. There are currently 67 ammonia plants with production capacities larger than 1,000 t/d. The total production capacity of these plants amounts to 23.8 million t/a, which is 28% of the total production capacity in China. In parallel, industry consolidation and urbanisation led to the closure of many small and inefficient plants which were not environmentally friendly and too close to surrounding cities.

## Catalysis

Catalyst is the key to ammonia synthesis. The solid catalyst screening and development by Alvin Mittasch, who tested thousands of catalysts in the 1900's, led to the discovery of a promoted iron catalyst which is still the basis and the most widely used ammonia synthesis catalyst in the world. Due to the strong demand and importance of the synthesis catalyst for the Chinese ammonia industry, several universities and research institutes engaged in domestic catalyst development. In 1951, the Nanjing Chemical Industry Company commercialised the A102 ammonia catalyst, which is a magnetite-based ammonia synthesis catalyst. Since then, many other improved versions (e.g. A110, A201 and A301 etc…), including a cobalt-promoted iron catalyst were developed and commercialised[2].

One of the significant breakthroughs in ammonia synthesis catalysts came in the 1980's, when researchers from Zhejiang University of Technology in Hanzhou invented a much more active ammonia synthesis catalyst containing the wustite form of iron. The wustite ammonia synthesis catalyst was licensed to Clariant Huajin (Panjin) Catalyst Company in 2000, which subsequently scaled up and optimised the production for commercial deployment. The catalyst was named *AmoMax-10* and exhibits much higher activity than magnetite-based ammonia synthesis catalysts, particularly at low temperatures and low pressures. Compared to a magnetite-based ammonia synthesis catalyst, a wustite-based catalyst has a lower oxygen content, which reduces the reduction duration by up to one day. AmoMax-10 was successfully commercialized in 2002. Since then, it has been widely used worldwide, with 92 global references within ten years and over 46 successful references in China.

## Current landscape

The on-going ammonia industry consolidation in China has resulted in many older and smaller plants being idled or shut down. On the other hand, there are many new coal-based ammonia projects under planning and construction. Therefore, it is challenging to verify active ammonia plants and their production capacity. However, based on available information, there are currently 436 ammonia plants in China, with 542 ammonia synthesis units, and the total ammonia production capacity was around 83 million t/a in 2013[3]. Annual ammonia production was 66.6 million t/a, indicating that there is significant ammonia overcapacity in China. However, it should be noted that around 10% of installed ammonia production capacity represents methanol and ammonia co-production units which might not always be used for ammonia production.

The major ammonia producers in China are listed in Table 1. The top ten companies account for around 30% of installed ammonia production capacity in the country. The Jinmei group, Yihua group and PetroChina group are the top three players. All of these major players are state or provincial government-owned companies which comply with the on-going industry consolidation while maintaining social stability.

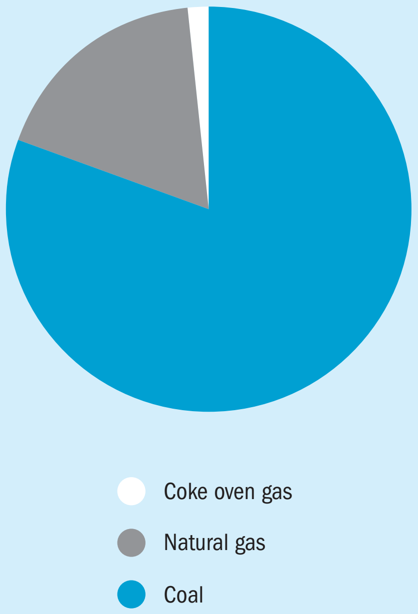
## Classification by location

Shangdong, Henan, Shanxi and Sichuan provinces operate the largest capacities, of around 6-9 million t/a per province. Shangdong, Henan and Sichuan each have a large population and are traditional agricultural provinces, so it is not surprising that these provinces have relatively large ammonia production capacities. As for Shanxi, the large ammonia production capacity is associated with the abundant coal reserves in the province, in particular anthracite, which is still widely used for ammonia production in mid-sized and smaller ammonia units. Developed cities like Beijing and Shanghai have no ammonia plants any more, and Guangdong province only has a limited capacity of 70,000 t/a.

Table 1: **Top ten ammonia producers in China**

| Company | Capacity, million t/a |
|---|---|
| Jinmei Group | 4.98 |
| Yihua Group | 4.13 |
| PetroChina Group | 3.89 |
| Yangmei Group | 2.99 |
| Jinkai Group | 2.08 |
| Sinopec Group | 1.79 |
| Yancon Group | 1.24 |
| Luxi Group | 1.15 |
| CNOOC | 1.05 |
| Henan Xinlianxin | 1.04 |

Fig 1: **Ammonia capacity by feedstock,** 2013



## Classification by feedstock

The classification of ammonia production capacity by feedstock is shown in Figure 1. Among the 542 ammonia units, there are 450 units using coal as feedstock, which accounts for around 80% of the total ammonia production capacity. This is in line with the abundant coal resources in China. The rest consist of mainly natural gas-fed ammonia plants and a few coke oven gas-based plants. There used to be several naphtha-based ammonia plants, but these have been either shut down or retrofitted to coal or natural gas feeds. Natural gas-fed ammonia synthesis technology is mature and shows very high process efficiency and reliability. However, China has limited natural gas reserves. In fact, the annual natural gas consumption per capita in China was only 80 $m^3$ in 2013, which is only 1/25 of the USA. The strong

Table 2: **Operating conditions and syngas compositions of different gasification technologies**

| Technology | Licensor | Pressure | Temperature | Steam:gas ratio | Syngas |
|---|---|---|---|---|---|
| Fixed bed | Air Liquide, BGL | Up to 4MPa | 900-1,200°C | <0.6 | CO 15%<br>$H_2$ 40%<br>$CH_4$ 12% |
| Fluidised bed | SES, KBR | Up to 1MPa | 900-1,100°C | <0.6 | CO 45%<br>$H_2$ 35%<br>$CH_4$ 5% |
| Entrained flow: | | | | | |
| Slurry feed/quench | GE, Texaco | Up to 8.7MPa | 1,300-1,500°C | 1.2-1.9 | CO 40%<br>$H_2$ 35% |
| Slurry feed/ radiant syngas cooler | Phillips 66 | Up to 4MPa | 1,300-1,500°C | 1.2-1.9 | CO 40%<br>$H_2$ 35% |
| Dry feed/quench | Siemens, GSP | Up to 4 MPa | 1,300-1,700°C | ~1.0 | CO 70%<br>$H_2$ 25% |
| Dry feed/radiant cooler | Shell | Up to 4MPa | 1,300-1,700°C | 0.2-0.3 | CO 70%<br>Hw 25% |

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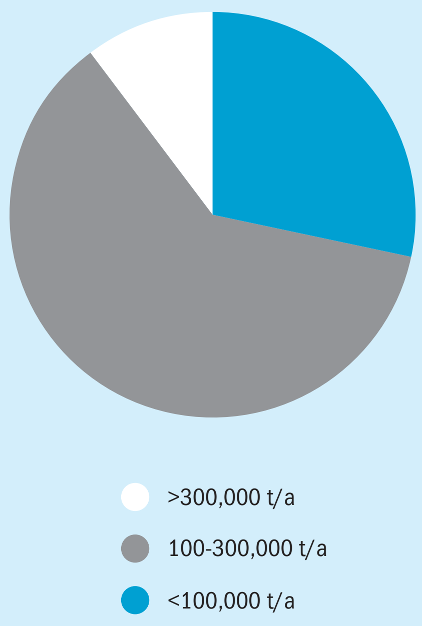
demand for natural gas and recent public concerns over smoggy weather in large cities have even lead to a high interest in coal to substitute natural gas (SNG) projects in China. China has abundant shale gas reserves of around 30 trillion cubic meters[4]. However the country is still lacking relevant fracking technology, a natural gas pipeline network and water accessibility in some key shale areas like Xinjiang province. Therefore, it is not expected that shale gas development will have a significant impact on the ammonia industry in China in the next ten years. Recent new regulations even forbid using natural gas as feedstock for new ammonia projects. The availability of natural gas, particularly in the winter season, has significant impacts on the operation and economics of the gas-based ammonia plants.

The successful commercialisation of entrained-flow gasification technology in the 1950's laid a solid foundation for the booming coal- based ammonia sector in China. Nearly all types of gasification technology have been demonstrated or commercialised in industrial plants in China. The complexity of gasification technology, coupled with diverse coal feedstocks, has resulted in vast accumulation of experience and lessons learned concerning coal gasification in the country. As we can see from Table 2, syngas compositions and steam/gas ratio varies significantly. The high CO percentage, coupled with low or high steam gas ratio in the raw syngas would create many challenges for the plant reliability, particularly the sour gas shift unit downstream of the gasifier. In general, coal-based ammonia plants face unique challenges of scale up, reliability and heat integration and optimisation to improve plant efficiency.

## Classification by size

Figure 2 summarises the classification of Chinese ammonia capacity by size. For large ammonia plants with a capacity ≥300,000 t/a, there are 67 units which accounted for 28.4% of the total installed ammonia production capacity in 2013. The largest single train ammonia unit in the country produces 600,000 t/a. Nearly all of these large ammonia plants are built for urea production. Mid-scale ammonia plants with a capacity between 100,000 t/a to 300,000 t/a still dominate in China; 308 units with a total capacity of around 60%. The 167 small plants with a capacity below 100,000 t/a will be challenged to sustain operations, and are expected to be gradually phased out unless they are coupled with high value-added downstream products. It is expected that many small and mid scale units will need to be retrofitted or shut down in order to be more competitive and to meet stringent environmental regulations.

Fig 2: **Ammonia production capacity by size,** 2013



## Classification by technology

The classification of ammonia units by synthesis technology is shown in Table 3. Casale takes the leading market share of 16.2%, followed by two Chinese domestic suppliers which are the key players in mid-scale ammonia plants. KBR was the pioneer in licensing large-scale ammonia technology to China and has a market share of 6.6%. For nearly 40% of the installed ammonia capacity, it is difficult to verify the converter technology and they are most likely still using an old high pressure synthesis technology.

## Classification by synthesis catalyst

The iron based ammonia synthesis catalyst is a relatively robust catalyst and the typical lifetime of ammonia synthesis catalyst in China is 10-20 years. It is important to use high activity catalyst in order to decrease energy consumption. The total ammonia catalyst production capacity in the country is over 10,000 t/a. The successful commercialisation of the highly active wustite-based catalyst AmoMax-10 has resulted in 46 references in 10 years in the ammonia industry in China. It should be noted that KBR licensed two 500,000 t/a ammonia plants to China Coal Group in Ordos which had been started up successfully with Clariant's AmoMax-10 catalyst in January 2014.

## New regulations and outlook

On Dec 21st 2012, the Ministry of Industry and Information Technology of China published guidelines for new entry conditions into the ammonia industry, aiming to accelerate industry restructuring, enforce environmental protection and better resource utilisation, and regulate industry investment, particularly avoiding inefficient processes and technology being selected for new ammonia plants. Below are a few key highlights of the new guidelines:

- Natural gas and anthracite-fed new ammonia plants are generally not allowed;
- Provinces which need to import coal from other regions are not allowed to build new ammonia plants;
- New large ammonia plants in northwestern regions with rich coal resources are encouraged;

Table 3: **Chinese ammonia capacity by ammonia converter technology,** 2013

| Company | Total installed capacity, million t/a | Capacity |
|---|---|---|
| Casale | 13.55 | 16.2% |
| Chenda | 11.31 | 13.5% |
| Anchun | 11.1 | 13.2% |
| KBR | 5.5 | 6.6% |
| Topsoe | 4.86 | 5.8% |
| Guochang | 3.79 | 4.5% |
| Uhde | 0.6 | 0.7% |
| Others | 33.13 | 39.5% |

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- The minimum scale of single train capacity of any new ammonia project is 1,000 t/d. The guideline also set thresholds of nominal energy consumption per unit of synthesized ammonia for both existing and new ammonia plants.

CTX (coal to ammonia, methanol, olefin, SNG, gasoline and diesel etc.) production has been booming in China in recent years. One of the reasons is that a company that invests in a CTX project will get access to coal reserves, although in some regions, direct sales of coal would be more profitable than converting the coal into chemicals or fuels. In order to boost local economic development, several provinces with rich coal reserves, e.g. Inner Mongolia and Xinjiang, have established regional regulations to require at least 50% of coal conversion to fuels or chemicals locally. Coal-to-ammonia is a relatively mature technology and requires moderate investment. Therefore, despite general overcapacity in the ammonia industry, we are aware that some new projects are planned or under construction. Most of the new projects are of large scale and close to regions with rich coal reserves. Total ammonia capacity is most likely not able to grow much further in the foreseeable future. However, the total capacity of large ammonia plants will grow from 23.8 million t/a in 2013 to around 32 million t/a by 2017, at compound annual growth rate (CAGR) of 8%.

More stringent environmental regulations and public concerns about pollution will also accelerate the upgrading and consolidation of the ammonia industry. New processes, technologies and catalysts for improving efficiency and reducing emissions will become increasingly important in this world largest ammonia market.

## Conclusions

The ammonia industry is and will continue to be strategically important for food security in China. Although China is the world's largest ammonia producer and total ammonia production capacity had reached a peak of just over 80 million t/a, the capacity of large ammonia plants will continue to grow at a CAGR of 8% in the next four years, associated with the on-going industrial consolidation. Abundant coal resources and limited gas and oil resources leads to the predominance of coal based ammonia plants in China. Stringent environmental regulations will require continuous innovation in process, technology and catalyst to improve the sustainability for the people in China and the world. ■

## Acknowledgement

The author would like to sincerely thank his Clariant colleagues Yuesheng Wang for the kind discussion and Ming Li for the kind assistance on ammonia plant data gathering and validation.

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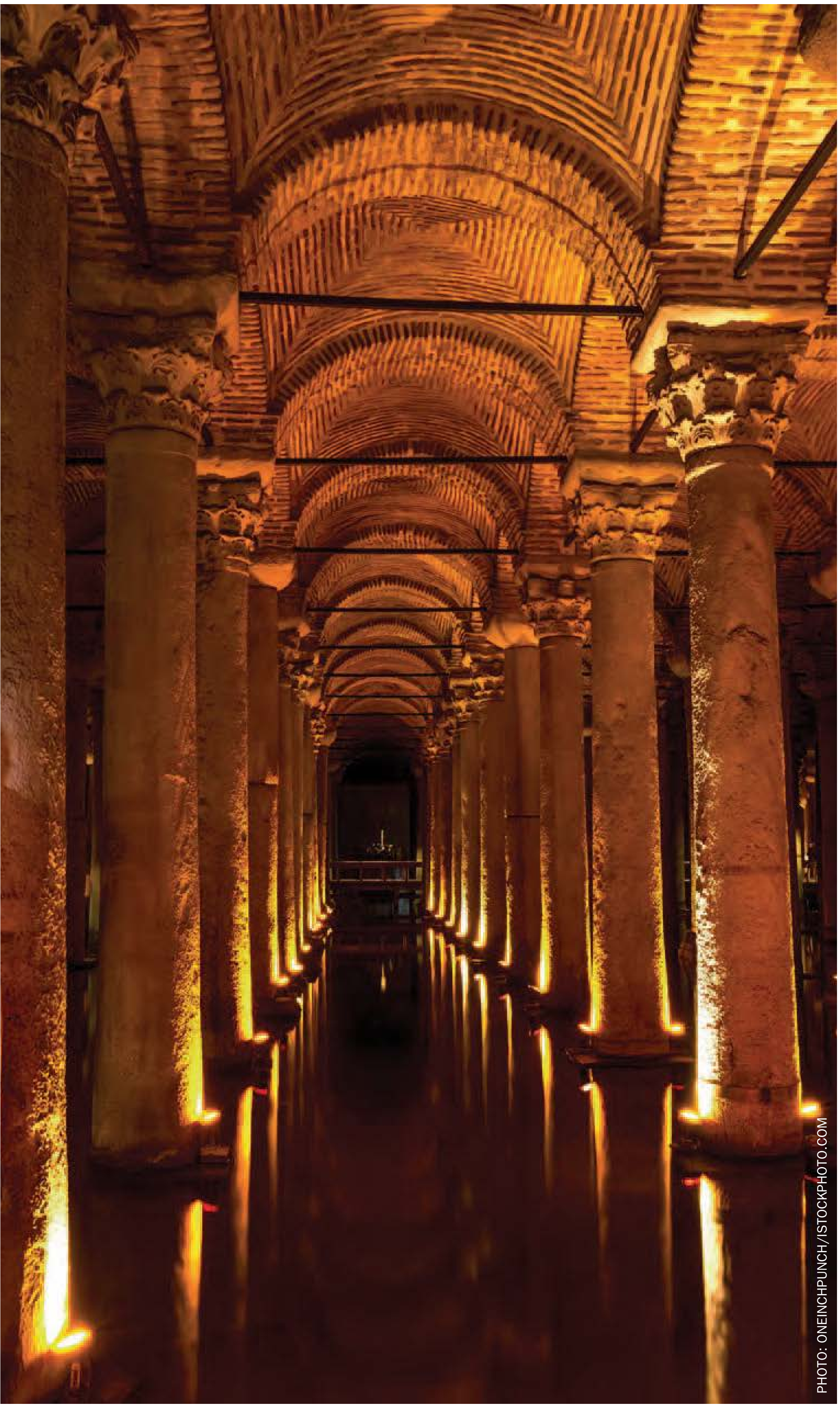
# Nitrogen+Syngas 2015

A review of papers presented at the Nitrogen+Syngas 2015 conference and exhibition, held at the Hilton Bomonti Hotel, Istanbul, from February 23rd – 26th.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*Underground of Basilica Cistern, Istanbul.*

The Nitrogen+Syngas conference continues to grow, this time achieving a record 660 delegates from over 50 countries, with good participation from Russia and the CIS states. Introducing the conference, CRU's Nicola Coslett reviewed current factors impacting upon the nitrogen industry, including recent events in the Ukraine, the falling rouble and oil price, and how the nitrogen sector was just as exposed to changes in global energy markets.

## Markets

**James Henderson** of the Oxford Institute of Energy Studies began by looking at gas, the feedstock for most global ammonia and methanol capacity. Gas markets were weakening prior to the oil price decline, he noted, partly due to competition from renewables and cheap US coal, as well as falling European demand due to economic stagnation. On the supply side, meanwhile, US gas production has risen 25% in five years. Shale production has continued to grow in spite of prices below $5.00/MMBtu, although it remains to be seen how the low oil price will impact on 'wet' shale plays that depend on natural gas liquids. In Asia, the effect of Fukushima is finally wearing off, with South Korea and Japan restarting nuclear plants, although this is balanced by the economic slowdown in China.

There is significant oversupply potential in the LNG market. Much depends on Chinese demand, which has great potential but also great uncertainty. Chinese shale production could be 30 bcm/year by 2020

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*James Henderson,*
*Oxford Institute of Energy Studies.*

and 100 bcm/year by 2030, but questions about pricing remain. LNG demand in India is likewise very price dependent. This uncertainty is magnified by the potential for large volumes of US LNG supply; there will be US LNG exports from the end of 2015, and then a significant build-up, possibly reaching 120 bcm/year by 2020. Additionally there is also new LNG supply from other sources such as Australia, Mozambique, Canada, Russia and Qatar. Russiais another wild card, able to supply Europe or China by pipeline. Gazprom now appears to have moved towards matching European hub prices and in general is no longer quite so focused on end users, but is rather looking towards more hub-based trading. Its eastern strategy has involved it in pipeline deals which will help to set the benchmark for prices in China.

In general, James reckoned that the three main factors likely to determine the shape of the gas market over the next couple of years were the future of Chinese demand, the extend of US supply on the international market, and the Russian response to these – Russia is able to balance the market it if chooses, or determine if it is loose or tight. Henry Hub prices could vary anywhere from $4.00-5.50/MMBtu depending on how these factors varied.

**Alistair Wallace** of CRU presented what he called a series of ‘silver linings’ to the current fall in nitrogen prices, which has been driven by overbuilding in medium term nitrogen capacity, and in particular huge Chinese capacity which has devalued the nitrogen market. More nitrogen capacity has been or will be build from 2010-2020 than in the previous 25 years, and 60% of this has been in China. But among more positive factors, demand fundamentals remain strong: crop prices have stabilised, supported by continued population growth and the macro-economy, with some small gains likely. This makes nitrogen relatively more affordable for farmers, and consumption is set to grow, especially per person, Alistair said, with consumption overall rising from 118 million tN in 2014 to 130 million tN in 2019. Nevertheless, new urea capacity over that period is set to ruse by 36.3 million tonnesN, of which 14.5 million tN will be in China, 5 million in North America, 4.4 million in Africa, and 4.2 million in the CIS. This overcapacity will mean that prices will be set by the cost of marginal producers – probably China – for the foreseeable future. Since 2013, China has set urea prices, not Ukraine.

Chinese production costs have been falling, as producers move from anthracite feedstock to bituminous and powdered coals. Anthracite prices are also falling from their 2011-12 peak as Chinese growth slows. This makes Chinese factory gate urea prices about $220/t, with f.o.b. equivalents $290-295 including tax. Chinese exports are likely to fall as demand rises, and coal and transport costs prices may also rise, raising floor prices to $335-340/t by 2019 – good news for anyone who can produce urea for less than that, and double the average inflation adjusted price of urea in the pre-2005 era. Likewise in Europe, Alistair noted, EU nitrate premiums are at a sustained high, allowing European producers to double revenues as compared to imported urea per tonne N.

**Mark Berggren** of MMSA looked at the methanol market, and echoed the point that the Chinese market now drives the world. Demand for methanol is accelerating into refined product substitutes even after oil price adjustments, and China is becoming self sufficient in methanol while remaining a high cost supplier. Methanol demand is set to rise from 72 million t/a in 2014 to 107 million t/a, he said, mainly for derivatives like gasoline (MTG) and methanol to olefins (MTO). Supply growth is now slowing in China, and most new capacity is actually in North America, some of it merchant capacity and some import substitution. This is likely to lead to regional oversupply and issues for producers in Trinidad and Venezuela who have traditionally relied on US demand. There may be a shakeout, although US MTG developments may help the local balance. There are also risks for US capacity if gas prices go much beyond $%.00/MMBtu. Methanol demand growth is mainly (75-80%) for Chinese energy and olefins uses.

Methanol prices are limited on the high side by derivative affordability, Mark said. DME has traditionally been the marginal buyer, especially in China, but MTO is becoming increasingly important. The price ceiling is probably somewhere in the $550/t range. The floor is set by the cost of Chinese coal-based production, as with ammonia, somewhere in the $270-300/t range. In the short term new supply and slowed China growth will extend the current correction, but longer term the pull from energy demand will keep supply tight and support pries. The Middle East remains the crucial pivot point on the trade front, and hosts the most ‘optional molecules’. Mark noted hat trade from North America to Asia was not yet “ready for prime time” and required new vessels. However, MTO producers are still making money even at current lower oil prices and there is much more investment in the pipeline, including a lot of non-integrated capacity.

Examining the FSU fertilizer outlook was **Mikhail Renkov** of Uralchem. There are over 60 ammonia units in the region, of which 32 are in Russia, with a combined capacity of 22 million tN/year, and production of 18.6 million t/a. Russia and Ukraine are the largest producers, and represent more than 85% of CIS output in urea and ammonium nitrate. The urea is mostly destined for export, and the AN for regional use. While anti-dumping issues militate against exports, the depreciation of the rouble has made export shipments more attractive for Russian suppliers. Russian production costs were competitive with China, he argued, and thus there is scope for more export-oriented capacity in Russia and the CIS. Four new plants are under development, two in Russia, one in Kazakhstan and one in Azerbaijan, but European market access is limited because of anti-dumping policies.

In an increasingly uncertain world managing risk is of the utmost importance. **Anil Chandramani** of the International Finance Corporation discussed the work of his organisation and how it could help in managing risk. The IFC is a UN body which supports projects in emerging markets which have more than 50% private equity. It was responsible for about $22 billion of investment finance in the 2014

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financial year, including 600 projects in 98 countries. The chemical and fertilizer sector represented about $8 billion of this (helping to fiancé $10-15 billion of projects), and the fertilizer sector is, he said, a strategic sector for the IFC and investments there have been increasing. In 2012 investment by IFC in fertilizers was more than $500 million, and included projects in India, Jordan, Senegal, Pakistan, Egypt, Columbia and China. Political risk is the largest one for such projects, and as the IFC board is composed of the 184 finance ministers of the member states, and so the IFC has access to these people. The IFC can also provide both debt and equity, and has a long term outlook, he said, which is good for a capital intensive industry like fertilizers. It can also provide expert advice on sustainability criteria and resource efficiency.

**Charles Hecker** of Control Risks turned from managing risk to predicting it. He foresaw 2015 as both a promising and challenging one for business. Challenging because the tensions between business and politics appear to be on the increase globally, with nationalism making itself felt as a potent force, and politicians less able to solve global crises. Businesses tend to prefer a world without borders, while politicians still move in a world with them, and those whose businesses cross borders are the most vulnerable to these forces. Technology is also making public opposition easier and faster. However, the promising side is that companies that anticipate risk and incorporate it into their strategies can enjoy the other side of risk; opportunity.

Turning to specifics, he said that Russia has an uncertain trajectory. Putin has rejected the liberal-democratic model of politics and the economy is suffering from the oil price and sanctions. Crackdowns on foreign companies were the first response to sanctions, and economically unstable countries behave unpredictably, making it a difficult climate for investment. In the Middle East and North Africa, declining US involvement is leaving a vacuum, although the Gulf kingdoms seem to be taking more responsibility for their own security than before. Control Risks remains optimistic (more than 50-50) about a deal over Iran, with a chance of opening up one of the last big emerging markets. However, increased intervention in Iraq and Syria will not end the conflict and in the worst case Iraq will fragment along sectarian lines like Syria has.

## Syngas technology and operations

A brace of catalyst papers began the technical side of the conference. Sulphur, arsenic, lead, mercury and chlorine can all poison reformer and shift catalysts, and have grown more prevalent in gas feeds. In response, **Prasant Kumar** of Clariant presented a portfolio of purification catalyst technology, as well as the *ShiftMax 230* low temperature shift catalyst, which is less sensitive to deactivation.

**Nenad Zevecic** of Petrokemija gave a very detailed run-down on a survey of a reformer charged with a high activity catalyst, while **William Whittenburger** of Johnson Matthey showcased the *CATACEL SSR* foil supported shift catalyst, which have higher heat transfer characteristics than usual, allowing reformer tube temperatures to be reduced by up to 25°C, decrease gas consumption by up to 5%, or increase reformer throughput (due to the lower pressure drop) by up to 15%, and allowing new reformers to be designed with up to a 10% capital cost reduction for the radiant box.

> **“EU nitrate premiums are at a sustained high, allowing European producers to double revenues as compared to imported urea per tonne N.**

**Dr Gasan Osojnik** of the Slovenian National Institute of Chemistry presented a new transition metal catalyst for syngas production from methane/carbon dioxide rich mixtures. Completing this section, Engro in Pakistan presented a case study on a failure of a transfer line between the primary and secondary reformers of their ammonia plant at Daharki. The plant was a relocated one, from the United States, and had suffered a similar problem during its service there. The refractory lining appeared to have failed, and was replaced. Dry-out was achieved using superheated process steam.

In a presentation he called ‘New Views through Old Doors’, **Peter Farnell** of JM Process Technology looked at reformer monitoring, and highlighted the advantages of near-IR (ca 1 micrometre) thermal imaging, and how it can correct for operator variability with conventional optical pyrometer measurements. Use of a fisheye lens also allows viewing of areas of the reformer which can’t normally be seen/reached.

## Methanol

A short methanol section chaired by Haldor Topsoe’s **Kristina Svennerburg** began one of the parallel streams on Wednesday. **Kevin Mowbray** of Johnson Matthey presented a case study of optimising an autothermal reformer in a large methanol plant, where in a standard catalyst set-up the alumina tiles used to hold down the catalyst bed can vaporise and condense in the top of the catalyst bed (leading to ruby formation on some of the catalyst particles), leading to increased pressure drop. Since 2007 JM have now used a stabilised ceramic hold down material with 90% less vaporisation, over a high activity guard bed, and the pressure drop has been minimal and the tiles and catalyst in an ‘as new’ condition as regards fouling.

**Kieran Lennox** of IPCOS discussed another case study of a Middle Eastern methanol plant constrained by its natural gas feed, where use of advance process control had allowed the operator to minimise fuel gas and optimise process gas, allowing production to be increased by 0.7%. Finally, **David Bray** of Haldor Topsoe described his company’s work with Chemanol to optimise downstream formaldehyde production from methanol plants.

## Ammonia technology

Energy Recovery offer their *IsoBoost* system which is able to recover mechanical energy from two differential pressure process solvent reams via a turbocharger. The simplicity of its operation, as described by **Andrea Gains German**, reduces maintenance and increases on-stream factor. The system has been proven in the oil and gas industry, and is now being offered for the ammonia industry.

While advanced process control systems are now common in the ammonia industry, issues can arise where process parameters interact and the system is trying to optimise interdependent variables. **James Gremillion** of Emerfson Process Management looked at ways of remedying this via matrix controllers and modern adaptive algorithms. Continuing the pro-

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cess control theme, leak detection was the topic for **Roberto Walder** of Smartec SA, who looked at the use of distributed fibreoptic sensors for monitoring pipes in chemical plants.

Squeezing more capacity out of existing ammonia plants is always a topic of interest for producers. **Fred Kessler** of ThyssenKrupp Industrial Solutions took a case study of a revamp at Kuibyshev Azot at Togliatti where front end solutions (eg replacing a fired heater via a preheat coil) and a new ammonia synthesis converter allowed a 30% increase in output. **Sergio Panza** of Casale also took a Russia ammonia plant as his revamp case study, in this case at Nevinnomyssk, where Casale were able to increase capacity from 1,700 t/d to 2,000 t/d.

**Mahesh Gandhi** of KBR focused instead on India, where KBR are looking at increasing plant capacities which are already operating at more than 130% of original nameplate up to 180% via expanding the radiant box of a primary reformer, the KRES reforming exchanger, and the addition of a secondary reformer.

## Compressors

A sometimes overlooked area of an ammonia plant is the rotating equipment. **Vasyl Martsynkovskyy** of TRIZ showed how selection of the right compressor assembly for syngas compressors can increase throughput by 2-4%. **Muhammad Hashim** and **Ahsan Sarfraz** of the Fatima Fertilizer Company described radial vibrations from a syngas compressor in their ammonia plant that led to modification of the oil seals, but this in turn led to high oil consumption by the replacement seals and leaks which eventually led to a plant shutdown. The mitigation strategy adopted was described. Finally, Mitsubishi Heavy Industries Compressor Corp showcased their latest designs for syngas compressor steam turbine modernisation, such as improvements in the turbine blade design for high speed and high output power.

## Energy efficiency

Reducing energy consumption is also a perennial issue for plant operators, and a session chaired by **John Brightling** of Johnson Matthey looked at this. **Arjun Vaz** of KPI described a new approach of using Multistage Integrated Chilling (MIC) as an option to avoid expensive compressor upgrades for incremental improvements in ammonia production, capable of achieving energy efficiency improvements of up to 15% depending on the plant and site, via a staged thermal coupling of the ammonia compression system with the process air compressor. **Francesco Rossi** of DVI Global Energy Services took a more holistic approach, via a comprehensive energy study to identify places where energy consumption and $CO_2$ emissions could be saved, including equipment and maintenance, pinch analysis, and the steam and power system.

The Linde Ammonia Concept, as described by **Berndt Kandziora**, generates nitrogen from an air separation unit and uses a nitrogen wash to generate pure, stoichiometric $H_2/N_2$ mixes for the ammonia converter. This leads to more optimal energy consumption and design flexibility to use anything from hydrogen rich industrial off-gas to light or heavy hydrocarbon feeds.

## Metallurgy

Metal dusting can be a major problem for high CO partial pressures and low steam:carbon ratios. **Vinay Deodeshmukh** of Haynes International showcased a nickel-chrome-molybdenum-copper alloy which can prevent the formation of intergranular $Cr_{23}C_6$ carbides, one of the major indicators of severe dusting and surface carburisation.

**Charles Thomas** of Quest Integrity presented the recommendations of the US Safety and Hazard Board on the Tesoro Anacortes accident, which was due to high temperature hydrogen attack in a heat exchanger. Specifically, the board recommended carbon -1/2 molybdenum steel be treated as carbon steel for the purposes of whether to use it in a specific application. However, Charles indicated that contributing factors like stress and post weld heat treatment make this recommendation over-proscriptive, and there had been other failures in the company's maintenance and risk management regime that had contributed to the accident.

**Marc Sluyters** of Gemaco, meanwhile, looked at sourcing of high performance stainless steels for urea and nitric acid plants, the differences between licensors specifications, and his company's ability to meet urgent demands for such materials.

## Nitric acid catalysts

In an era of high platinum group metal prices, minimising cost to nitric acid producers becomes all the more important, and the major suppliers all have different strategies for achieving this. Heraeus focus on primary catalyst systems, designing their FTC-HR gauze for low $N_2O$ emissions and the FTC-LL system for low platinum loss. Johnson Matthey, in partnership with RS Bruce, tailor gauze packs for low installed metal content and low metal loss, and also offer cleaning and recovery services. Unicore now offer tailored solutions via their MPAC gauze packs and data analysis techniques, offering packs with over 5 types of wire and 10 pattern types, allowing the operator to tune for durability, product yield or lower weight/metal loss.

## Urea technology

The urea technology session, chaired by *Nitrogen+Syngas* Technical Editor **Lisa Connock**, began with a paper by **Mark Brouwer** of UreaKnowHow.com, covering the latest trends in urea process technologies, which can be found elsewhere in this issue, on pages 44-48. NIIK's **Alexander Vorobjev**, meanwhile, showcased his company's vortex mixing technology for urea reactors, which can give up to a 1% increase in $CO_2$ conversion with no increase in $CO_2$ pressure at the discharge and a saving in medium pressure steam. **Luc Dietjens** of Stamicarbon advocated rigorous plant modelling of a urea plant, including 350 process streams and 6,000 process variables, as part of Stamicarbon's new Advance Consult, Advance Insight and Evolve Optimiser offerings.

**Klaus Noelker** of ThyssenKrupp Industrial Solutions described TKIS' experience with a urea plant revamp at the Egyptian Fertilizers Co. Revamping of urea plants can be problematic as they consist mainly of high pressure equipment and piping. The solution was to add a separate medium pressure section licensed by Stamicarbon (the original designer of the plant).

## Urea operations

A number of nitrogen plant operators and licensors presented real world operating experiences. **Asim Qureshi** and **Syed Usman Ahmed** of Engro Fertilizers described issues with their own plant, including a leaking medium pressure

## UreaKnowHow.com workshop

For the fifth time UreaKnowHow.com organised a pre-conference workshop, this time on 23 February 2015. More that fifty participants attended the workshop, which was this time run as a Questions & Answer format, so that each participant could bring up their questions and all others could answer and share their experiences. UreaKnowHow.com was represented by Jo Eijkenboom (mechanical), Giel Notten (corrosion), George van Bommel (product quality) and Mark Brouwer (process).

Topics discussed were:

- Is it possible to insulate a HP reactor during operation?
- How to increase reliability?
- How to reduce energy consumption figures?
- How OPP Odessa debottlenecked their $CO_2$ compressor by adding liquid $CO_2$ to the synthesis section?
- When can purified process condensate be used directly as boiler feed water?
- How to handle impact testing criteria for HP piping components (-33C)?
- What is the experience with Chinese contractors?
- What are the NDT techniques for bimetallic stripper tubes?
- What are the HPCC failure modes for various materials of construction?
- What are the minimum tube wall thicknesses for HP heat exchangers?
- How to secure urea product quality during handling and storage?
- How to control moisture content in a fluid bed granulation?
- What are the benefits of using Stamicarbon coating technology for prills?
- How can Solex reduce the temperature of prills and granules?

The chosen format led to many questions being asked and good and detailed technical discussions took place, especially because the practical experience of more than thirty managers and engineers from urea producers was present. But the licensors Stamicarbon, Saipem, Casale and NIIC also participated and shared their philosophies and views on several topics. Feedback from the participants was very positive and UreaKnowHow say that they are very pleased to have realised such an open constructive discussion between licensors which will surely increase safety and performance in the urea industry. ■

decomposer, caused by gas supply interruptions which led to plant trips and subsequent thermal shocks and stresses, and corrosion. The solution has been to reduce the bottom holder temperature of the MPD and instigate an investigation into the heat exchanger tubes for a better understanding of the situation.

**R Festi** of Saipem presented a look at the first decade of operations at the Omifco Fertilizer Complex in Oman. The first year threw up a number of problems, including vibration in a boiler feed water pump, a failure of a syngas compressor turbine, and a major ammonia leak incident in the urea plant, but over the intervening years the plant has consistently run at 110% of ammonia and 120% of nameplate urea capacity.

**Roberto Gorza** of Casale highlighted a case of corrosion in a high pressure condenser in a urea plant. Repairs had been carried out including plugging of various tubes, and this was subsequently followed by a patch plate, but this is only a temporary measure and was not judged to be suitable for long service.

**Maria Yanovskaya** of Haldor Topsoe looked at integration of ammonia, methanol and hydrogen production at Shchekinoazot in Russia. Methanol production was commissioned in 2011, hydrogen production began in 2012, and last year an ammonia side stream came on-line. **Kinya Ishizawa** of Mitsubishi Heavy Industries reported in the new Mendeleevsk fertilizer complex in Tatarstan, Russia, which is an ammonia-urea unit with a methanol and urea formaldehyde side-stream, and which is now in start-up.

## Fertilizer finishing

NIIK now offer their high speed drum granulation technology for urea plants, which, as described by **Natalia Kargaeva** can enhance finishing capacity at a plant with an existing prill tower by taking below-spec fines and growing them into granules using additional urea melt.

Another granulation technology, this time from China, was presented by **Ken Monstrey** of Green Granulation Technology. This is a cold recycle fluidised bed urea granulation process which keeps the granulator and cooler in-line and which requires less construction and a lower height building, as well as reduced power consumption.

**Gert-Jan de Geus** of OCI Nitrogen described what he called 'Project Cool'; as part of an agreement with the Dutch government, OCI aimed to debottleneck the CAN capacity at Geleen, which necessitated replacing the fluid bed coolers with a vertical shell and tube design. The selected model was a BXC Coperion design, installed initially only in one line as a test, and then the other two once successful. Dust emissions have been reduced to zero, with a saving in energy costs, after some initial mass flow problems were solved. ■

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# The future of Ukraine's nitrogen industry

An update on how the conflict with Russia could affect Ukraine's gas supplies and its downstream production of ammonia, urea and ammonium nitrate.

In addition to the human misery that it has produced, Ukraine's conflict with pro-Russian separatists – now a year old – raised worries at the time of its outbreak of a shutdown of ammonia and urea supplies out of the Black Sea; the source of about 20% of globally traded ammonia and 5-10% of urea. The worst fears – about the conflict and its affect on fertilizer markets – appear not to have been realised, but the Ukrainian economy in general and the nitrogen industry in particular are nevertheless facing considerable pressures.

Ukraine's nitrogen industry is mostly in the hands of Group DF (via its Ostchem holding company), which owns four of the six producing locations, at Rivne, Cherkassy, Severodonetsk and Stirol/Gorlovka. It also markets product from the state-owned Odessa Port Plant (OPZ) at Yuzhnyy. The final producer, DneproAzot, is leased to fellow Privat Group company and gas supplier Ukrnafta. Most of these plants have avoided direct consequences of the fighting, but the two largest, Severodonetsk and Stirol are both in the east of the country and near to the combat zone. Stirol in particular was shelled last year and has been shut down since the start of the conflict. Severodonetsk was shut down in April 2014, and has seen fighting pass near the plant, but is now in government-controlled territory and re-started ammonium nitrate production in December 2014. Nevertheless, Ukrainian ammonia production was down 30% in 2014 as compared to 2013.

## Gas supply

In the absence of large-scale conflict and with the port of Odessa remaining open, the major threat to Ukrainian production has now become natural gas supply. Ukraine imports about 60% of its gas requirements, and in 2013 all but a tiny amount of that came across the eastern border from Russia. Disputes over pricing and payments for gas have rumbled on between Russia and Ukraine ever since the collapse of the Soviet Union, occasionally leading to gas supplies being stopped, but the crisis has brought matters to a head again. Once the conflict began Gazprom declared a previous deal on gas supply and pricing (signed by ousted pro-Russian president Yanukovich) void and hiked gas prices from $7.45/MMBtu to $13.45/MMBtu and demanded payment of $4.5 billion in gas debts. A deal was finally reached after six months of gas supply interruption in October 2014 allowing gas to flow again, with Ukraine paying per shipment rather than using credit terms. This expires in March, but is expected to be renegotiated.

Nevertheless, in spite of the fall in global oil prices, Ukraine has still paid an average of $12.50/MMBtu for the gas it received from Russia this winter. Some gas has also come from western Europe under reverse flow arrangements – Ukraine has also been a major conduit for Russian gas to Europe, although the opening of other new pipelines and LNG terminals have reduced a lot of the impact closing Ukrainian pipelines once used to have on Europe. Indeed, Ukraine has tried to hike transit costs the Gazprom pays as part of its negotiation strategy. For the moment, Ukraine seems to have enough gas, but the question for nitrogen producers is at what cost. Group DF said in July last year that it had enough gas supplies to last it until February 2015, but Gaz Ukrainy, a subsidiary of state gas company Naftogaz, has asked a regional court to declare Group DF's Cherkassy Azot unit bankrupt, based on overdue debts of 181.1 million hryvna ($11.2 million) over gas payments. Group DF has also faced issues (now resolved) with Gazpromexport bank over loan payments.

Ukraine has long been a swing nitrogen producer, and until China recently overtook that role was effectively the marginal producer. The worry for Ukraine is that cheap Chinese urea on the back of falling coal costs has effectively priced Ukraine out of the market.

## The economy

The other worry for Ukraine is the general state of the economy. The country is reportedly on the brink of economic collapse and has recently secured a $17.5 billion IMF bailout on top of the $40 billion it received in February. Debt stands at 100% of GDP, and the IMF is demanding reforms that have been very unpopular. The combat is disrupting the country's eastern industrial district, and the hryvnia lost 70% of its value against the dollar since the start of the conflict. This also affects Russia of course, and in theory, the collapse in the value of the hryvnia and rouble should be something of a boon for export-oriented Russian and Ukrainian producers, as their domestic costs are rouble denominated, and their product prices dollar denominated. However, EuroChem recently reported losses for 2014 of $578 million, after a profit of $387 million in 2013, mainly due to $1.5 billion in additional costs in servicing the company's dollar-denominated debt.

Ukraine's nitrogen industry has been in a difficult situation for some years due to high gas costs. The fear must be for the industry now that the conflict will provide the final straw that forces closure of the remaining operational units. ■

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# Nitrogen project listing 2015

## Current and future projects for new ammonia, urea, nitric acid and ammonium nitrate capacity

| CONTRACTOR | LICENSOR | COMPANY | LOCATION | PRODUCT | M T/D | STATUS | DATE |
|---|---|---|---|---|---|---|---|
| **ARGENTINA** | | | | | | | |
| n.a. | n.a. | Profertil | Bahia Blanca | Ammonia | 2,130 | RE | 2015 |
| n.a. | n.a. | Profertil | Bahia Blanca | Urea | 3,700 | RE | 2015 |
| **AUSTRALIA** | | | | | | | |
| Ausenco | n.a. | Orica | Newcastle | Ammonium nitrate | 1,000 | RE | 2015 |
| n.a. | n.a. | IncitecPivot | Kooragang I | Ammonium nitrate | 1,000 | P | 2017 |
| Technicas Reunidas | Espindesa | Yara Pilbara Nitrates | Burrup | Nitric Acid | 760 | C | 2015 |
| Technicas Reunidas | Espindesa | Yara Pilbara Nitrates | Burrup | Ammonium nitrate | 965 | C | 2015 |
| **AZERBAIJAN** | | | | | | | |
| Samsung | Haldor Topsoe | SOCAR | Sumgait | Ammonia | 1,200 | UC | 2017 |
| Samsung | Stamicarbon | SOCAR | Sumgait | Urea | 2,000 | UC | 2017 |
| **BANGLADESH** | | | | | | | |
| China Chengda | KBR | BCIC | Shahjalal | Ammonia | 1,000 | C | 2015 |
| China Chengda | Stamicarbon | BCIC | Shahjalal | Urea | 1,760 | C | 2015 |
| Uhde India Pvt | UFT | Kafco | Chittagong | Urea | 2,250 | RE | 2016 |
| **BELARUS** | | | | | | | |
| ThyssenKrupp I.S. | ThyssenKrupp I.S. | Grodno Azot | Grodno | Nitric acid | 1,200 | UC | 2016 |
| ThyssenKrupp I.S. | ThyssenKrupp I.S. | Grodno Azot | Grodno | Ammonium nitrate | 3,500 | UC | 2016 |
| **BOLIVIA** | | | | | | | |
| Samsung | KBR | YPFB | Bulo Bulo | Ammonia | 1,200 | UC | 2016 |
| Samsung | TEC | YPFB | Bulo Bulo | Urea | 2,100 | UC | 2016 |
| **BRAZIL** | | | | | | | |
| Technip, TEC | Haldor Topsoe | Petrobras | Uberaba | Ammonia | 1,500 | BE | 2017 |
| Tecnimont | KBR | Petrobras | Tres Lagoas | Ammonia | 2,200 | UC | 2017 |
| Tecnimont | Stamicarbon, UFT | Petrobras | Tres Lagoas | Urea | 3,600 | UC | 2017 |
| n.a. | Casale | Vale Fertilizantes | Placaguera | Ammonia | 600 | RE | 2015 |
| **CANADA** | | | | | | | |
| n.a. | n.a. | Koch Nitrogen | Brandon | Ammonia | +270 | RE | 2015 |
| Casale | Casale | Koch Nitrogen | Brandon | Urea | 700 | RE | 2016 |
| Kiewit, Tecnimont | KBR | Iffco | Quebec | Ammonia | 2,200 | P | On hold |
| Kiewit, Tecnimont | Stamicarbon | Iffco | Quebec | Ammonia | 3,850 | P | On hold |
| **CHINA** | | | | | | | |
| Casale | Casale | Inner Mongolia Manshi | Erdos | Ammonia | 1,630 | RE | 2016 |
| Casale | Casale | Air Liquide China | LianJiang | Ammonia | 890 | RE | 2015 |
| Casale | Casale | Henan Junhua | Zhumadian, Henan | Ammonia | 2,000 | RE | 2016 |
| Casale | Casale | Henan Jinkau | Kaifeng, Henan | Ammonia | 2,000 | RE | 2016 |
| Casale | Casale | Shenua Ningxia | Ningxia | Ammonia | 500 | RE | 2016 |
| n.a. | KBR | Huajin | Kuche, Xinjiang | Ammonia | 1,500 | RE | 2014 |
| CECC | KBR | Inner Linggu Chem Co | Yixing, Jingsu | Ammonia | 1,500 | UC | 2016 |
| Wuhuan Engineering | Haldor Topsoe | Hegang Huahe Coal | Hegang, Heilongjiang | Ammonia | 1,050 | C | 2015 |
| Wuhuan Engineering | Stamicarbon | Hegang Huahe Coal | Hegang, Heilongjiang | Urea | 1,860 | C | 2015 |
| China Chengda | Stamicarbon | Inner Mongolia Erdos | Ordos | Urea | 2.860 | C | 2015 |
| China Chengda | Stamicarbon | Inner Linggu Chem Ind | Yixing, Linggu | Urea | 2,700 | UC | 2015 |
| n.a. | Stamicarbon | Inner Mongolia Huajin | Panjin | Urea | 2,860 | BE | 2017 |

**KEY**

| | | | |
|---|---|---|---|
| BE: Basic Engineering | CA: Contract Awarded | FS: Feasibility Study | RE: Revamp |
| C: Completed / Commissioning | DE: Design Engineering | P: Planned / Proposed | UC: Under Construction |

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## Current and future projects for new ammonia, urea, nitric acid and ammonium nitrate capacity

| CONTRACTOR | LICENSOR | COMPANY | LOCATION | PRODUCT | M T/D | STATUS | DATE |
|---|---|---|---|---|---|---|---|
| **EGYPT** | | | | | | | |
| Tecnimont | KBR | Kima | Aswan | Ammonia | 1,200 | UC | 2016 |
| Tecnimont | Stamicarbon | Kima | Aswan | Urea | 1,575 | UC | 2016 |
| ThyssenKrupp I.S. | UFT | EFC | Ain Sukhna | Urea | 2,250 | RE | 2015 |
| ThyssenKrupp I.S. | ThyssenKrupp Uhde | MOPCO | Damietta | Ammonia | 2 x 1,200 | UC | n.a. |
| ThyssenKrupp I.S. | Stamicarbon, UFT | MOPCO | Damietta | Urea | 2 x 1,925 | UC | n.a. |
| ThyssenKrupp I.S. | ThyssenKrupp I.S. | EHC | Suez | Nitric acid | 850 | C | 2014 |
| ThyssenKrupp I.S. | ThyssenKrupp I.S. | EHC | Suez | Ammonium nitrate | 1,050 | C | 2014 |
| **FRANCE** | | | | | | | |
| Casale | Casale, UFT | Borealis Chimie | Grandpuits | Urea | 850 | RE | 2016 |
| **GABON** | | | | | | | |
| Technip | Haldor Topsoe | Gabon Fertilizer Co | Port Gentil | Ammonia | 2,200 | DE | 2017? |
| Technip | Saipem, UFT | Gabon Fertilizer Co | Port Gentil | Urea | 3,850 | DE | 2017? |
| **GERMANY** | | | | | | | |
| n.a. | Casale, Toyo | SKW Stickstoffwerke | Lutherstadt | Ammonia | 1,900 | RE | 2015 |
| **HUNGARY** | | | | | | | |
| n.a. | ThyssenKrupp I.S. | Nitrogenmuvek | Petfurdo | Ammonium nitrate | 1,550 | UC | 2016 |
| **INDIA** | | | | | | | |
| Casale | Casale | Krubhco | Shahjahanpur | Urea | 1,310 | RE | 2015 |
| PDIL | KBR | Matix Fert & Chem | Panagarh | Ammonia | 2,200 | UC | 2015 |
| Saipem | Saipem | Matix Fert & Chem | Panagarh | Urea | 3,850 | UC | 2015 |
| n.a. | n.a. | Deepak Fertilizers | Paradip | Ammonium nitrate | 1,000 | P | 2017 |
| **INDONESIA** | | | | | | | |
| TEC | KBR | PAU | Sulawesi | Ammonia | 1,900 | UC | 2016 |
| TEC | KBR | Kaltim | Bontang | Ammonia | 2,700 | C | 2015 |
| TEC | TEC | Kaltim | Bontang | Urea | 3,500 | C | 2015 |
| TEC/PT Rekayasa | KBR | Pusri | Palembang | Ammonia | 2,750 | UC | 2016 |
| TEC/PT Rekayasa | TEC | Pusri | Palembang | Urea | 2,000 | UC | 2016 |
| n.a. | ThyssenKrupp I.S. | Bakri | Kalimantan | Nitric acid | 750 | DE | On hold |
| n.a. | ThyssenKrupp I.S. | Bakri | Kalimantan | Ammonium nitrate | 900 | DE | On hold |
| **IRAN** | | | | | | | |
| Casale | Casale | Lordegan Petrochemical | Lordegan | Ammonia | 2,050 | UC | 2015 |
| Hampa | Stamicarbon | Lordegan Petrochemical | Lordegan | Urea | 3,250 | UC | 2016 |
| Hampa | Stamicarbon | Lordegan Petrochemical | Golestan | Urea | 3,250 | P | On Hold |
| Hampa | Stamicarbon | Zanjan Petrochemical | Zanjan | Urea | 3,250 | DE | 2017 |
| n.a. | Stamicarbon | Pardis Petrochemical | Pars | Urea | 3,250 | C | 2015 |
| **IRAQ** | | | | | | | |
| NFC | KBR | NFC | Baiji | Ammonia | 1,200 | RE | On hold |
| NFC | Stamicarbon | NFC | Baiji | Urea | 2,250 | RE | On hold |
| **MALAYSIA** | | | | | | | |
| MHI | Haldor Topsoe | Petronas | Siptang | Ammonia | 2,100 | UC | 2015 |
| MHI | Saipem, UFT | Petronas | Siptang | Urea | 3,500 | UC | 2015 |
| **NIGERIA** | | | | | | | |
| TEC/Daewoo | KBR | Indorama | Port Harcourt | Ammonia | 2,400 | UC | 2016 |
| TEC/Daewoo | TEC | Indorama | Port Harcourt | Urea | 4,000 | UC | 2016 |
| Saipem | Haldor Topsoe | Dangote Fertilizer Ltd | Agenbode | Ammonia | 2 x 2,200 | UC | 2016 |
| Saipem | Saipem, UFT | Dangote Fertilizer Ltd | Agenbode | Urea | 2 x 3,850 | UC | 2016 |
| **OMAN** | | | | | | | |
| n.a. | Linde, Haldor Topsoe | Takamul | Salalah | Ammonia | 1,000 | P | 2018 |

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## Current and future projects for new ammonia, urea, nitric acid and ammonium nitrate capacity

| CONTRACTOR | LICENSOR | COMPANY | LOCATION | PRODUCT | M T/D | STATUS | DATE |
|---|---|---|---|---|---|---|---|
| **PERU** | | | | | | | |
| Tecnicas Reunidas | n.a. | Nitratos del Peru | Paracas | Ammonia | 2,060 | UC | 2015 |
| Tecnicas Reunidas | Espindesa | Nitratos del Peru | Paracas | Nitric acid | 925 | UC | 2015 |
| Tecnicas Reunidas | Espindesa | Nitratos del Peru | Paracas | Ammonium nitrate | 1,060 | UC | 2015 |
| **POLAND** | | | | | | | |
| Casale | Casale, INS | Grupa Azoty | Kedzierzyn | Ammonia | 1,350 | RE | 2015 |
| Casale | Casale, Topsoe | Grupa Azoty | Police | Ammonia | 950 | RE | 2014 |
| Casale | Casale | Grupa Azoty | Pulawy | Urea | 2,000 | RE | 2015 |
| **ROMANIA** | | | | | | | |
| Chemoprojekt | Casale | Azomures | Targu Mures | Ammonia | 2 x 1,050 | RE | 2016 |
| Chemoprojekt | Stamicarbon | Azomures | Targu Mures | Urea | 1,425 | RE | 2016 |
| **RUSSIA** | | | | | | | |
| Casale | Casale, Toyo | EuroChem | Novomoskovsk | Ammonia | 1,700 | RE | 2015 |
| Casale/NIIK | Casale, NIIK | EuroChem | Novomoskovsk | Urea | 2,000 | RE | 2014 |
| n.a. | NIIK | EuroChem | Novomoskovsk | UAN | 1,200 | DE | 2015 |
| NIIK | NIIK, Stamicarbon | Minudobrenija Perm | Perm | Urea | 1,720 | RE | 2016 |
| Casale/NIIK | Casale, NIIK | EuroChem | Nevinnomyssk | Ammonia | 2,000 | RE | 2014 |
| Casale/NIIK | Casale, NIIK | Kuibyshev Azot | Togliatti | Ammonia | 1,340 | RE | 2015 |
| Casale | Casale | PhosAgro | Cherepovets | Ammonia | 1,700 | RE | 2015 |
| NIIK | NIIK | PhosAgro | Cherepovets | Urea | 1,600 | RE | 2015 |
| Casale | Casale | Togliatti Azot | Togliatti | Ammonia | 1,200 | RE | 2015 |
| Casale | n.a. | Togliatti Azot | Togliatti | Urea | 2,600 | RE | 2017 |
| n.a. | NIIK | Rosstroy | Novocherkassk | Ammonia | n.a. | FS | n.a. |
| n.a. | NIIK | Rosstroy | Novocherkassk | Urea | n.a. | FS | n.a. |
| NIIK | NIIK, Topsoe | JSC Acron | Novgorod | Urea | 4 x 2,000 | RE | 2015 |
| Tecnimont | KBR, NIIK | EuroChem | Kingisepp | Ammonia | 2,700 | BE | n.a. |
| Tecnimont | KBR | EuroChem | Nevinnomyssk | Ammonia | 2,700 | BE | n.a. |
| MHI, NIIK | n.a. | JSC Ammoni | Tatarstan | Ammonia | n.a. | DE | n.a. |
| MHI, NIIK | n.a. | JSC Ammoni | Tatarstan | Urea | n.a. | DE | n.a. |
| n.a. | Saipem, UFT | ICM | St Petersburg | Urea | n.a. | DE | n.a. |
| NIIK/MHI | Haldor Topsoe | JSC Ammoniy | Mendeleevsk | Ammonia/Methanol | 2,050 | UC | 2015 |
| NIIK/MHI | Saipem, UFT | JSC Ammoniy | Mendeleevsk | Urea | 2,050 | UC | 2015 |
| MHI/Sojitz | Haldor Topsoe | PhosAgro | Cherepovets | Ammonia | 2,200 | BE | 2017 |
| Chemprojekt | Stamicarbon | PhosAgro | Cherepovets | Urea | 1,500 | BE | 2017 |
| **SAUDI ARABIA** | | | | | | | |
| Saipem | Saipem, UFT | Safco | Al Jubail | Urea | 3,250 | C | 2015 |
| Daelim | ThyssenKrupp I.S. | Ma'aden | Ras al Khair | Ammonia | 3,300 | UC | 2017 |
| **SLOVAKIA** | | | | | | | |
| Chemoprojekt | Haldor Topsoe | Duslo Sala | Sala | Ammonia | 1,600 | RE | 2018 |
| Chemoprojekt | Stamicarbon | Duslo Sala | Sala | Urea | 900 | RE | 2014 |
| **SPAIN** | | | | | | | |
| Casale | Casale, ThyssenKrupp | I.S. Fertiberia | Puertollano | Ammonia | 600 | RE | 2015 |
| Casale | Casale | PCS Nitrogen | Point Lisas | Ammonia | 1,150 | RE | 2015 |
| **SWEDEN** | | | | | | | |
| Chemoprojekt | Casale | Yara | Koping | Nitric acid | 685 | CA | 2017 |
| n.a. | n.a. | Yara | Koping | Ammonium nitrate | 1,360 | RE | 2017 |
| **TANZANIA** | | | | | | | |
| Ferrostaal | Haldor Topsoe | Tanzanian Petroleum | Mtwara | Ammonia | 2,200 | DE | 2018 |
| Ferrostaal | n.a. | Tanzanian Petroleum | Mtwara | Urea | 4,000 | DE | 2018 |
| **TRINIDAD & TOBAGO** | | | | | | | |
| Casale | Casale | PCS Nitrogen | Point Lisas | Ammonia | 1,150 | RE | 2015 |

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### Current and future projects for new ammonia, urea, nitric acid and ammonium nitrate capacity

| CONTRACTOR | LICENSOR | COMPANY | LOCATION | PRODUCT | M T/D | STATUS | DATE |
|---|---|---|---|---|---|---|---|
| **TURKEY** | | | | | | | |
| ThyssenKrupp I.S. | ThyssenKrupp I.S. | Bagfas | Bandima | Nitric acid | 1,195 | UC | 2015 |
| ThyssenKrupp I.S. | ThyssenKrupp I.S. | Bagfas | Bandima | Ammonium nitrate | 1,550 | UC | 2015 |
| ThyssenKrupp I.S. | ThyssenKrupp I.S. | Bagfas | Bandima | CAN | 2,000 | UC | 2015 |
| n.a. | Haldor Topsoe | Eti Bakir | Mardin | Ammonia | 300 | P | 2017 |
| **TURKMENISTAN** | | | | | | | |
| Kawasaki, Sojitz | KBR | Turkmenkhimiya | Mary | Ammonia | 1,200 | C | 2014 |
| Kawasaki, Sojitz | Stamicarbon, UFT | Turkmenkhimiya | Mary | Urea | 1,925 | C | 2014 |
| MHI | Haldor Topsoe | Turkmenkhimiya | Garabogaz | Ammonia | 2,000 | CA | 2018 |
| MHI | Saipem, UFT | Turkmenkhimiya | Garabogaz | Urea | 3,500 | CA | 2018 |
| **UNITED STATES** | | | | | | | |
| ThyssenKrupp I.S. | ThyssenKrupp I.S. | CF Industries | Donaldsonville, LA | Ammonia | 3,300 | UC | 2015 |
| ThyssenKrupp I.S. | Stamicarbon, UFT | CF Industries | Donaldsonville, LA | Urea | 3,500 | UC | 2015 |
| ThyssenKrupp I.S. | ThyssenKrupp I.S. | CF Industries | Donaldsonville, LA | Nitric acid | 1,515 | UC | 2015 |
| ThyssenKrupp I.S. | ThyssenKrupp I.S. | CF Industries | Donaldsonville, LA | UAN | 4,300 | UC | 2015 |
| ThyssenKrupp I.S. | ThyssenKrupp I.S. | CF Industries | Port Neal, IA | Ammonia | 2,200 | UC | 2016 |
| ThyssenKrupp I.S. | Stamicarbon, UFT | CF Industries | Port Neal, IA | Urea | 3,490 | UC | 2016 |
| OCI Construction | KBR | OCI Nitrogen | Wever, IA | Ammonia | 2,000 | UC | 2015 |
| OCI Construction | Stamicarbon, UFT | OCI Nitrogen | Wever, IA | Urea | 2,150 | UC | 2015 |
| OCI Construction | ThyssenKrupp I.S. | OCI Nitrogen | Wever, IA | Nitric acid | 1,530 | UC | 2015 |
| OCI Construction | ThyssenKrupp I.S. | OCI Nitrogen | Wever, IA | Ammonium nitrate | 1,900 | UC | 2015 |
| OCI Construction | ThyssenKrupp I.S. | OCI Nitrogen | Wever, IA | UAN | 4,300 | UC | 2015 |
| KBR | Stamicarbon, UFT | Agrium | Borger, TX | Urea | 1,800 | RE | 2015 |
| KBR, Casale | KBR, Casale | Agrium | Borger, TX | Ammonia | 1,900 | RE | 2016 |
| IHI | Stamicarbon | Dakota Gasification | Beulah, ND | Urea | 1,100 | UC | 2017 |
| Casale | Casale, KBR | PCS Nitrogen | Lima, OH | Ammonia | 1,650 | RE | 2015 |
| KBR | KBR | Dyno Nobel | Waggaman, LA | Ammonia | 2,400 | UC | 2016 |
| n.a. | Weatherly | El Dorado | Union County, AS | Nitric acid | 1,100 | UC | 2015 |
| KBR | KBR | Midwest Fertilizer Co | Mt Vernon, IN | Ammonia | 2,200 | CA | 2017 |
| Tecnimont | Stamicarbon | Midwest Fertilizer Co | Mt Vernon, IN | Urea | 2,200 | CA | 2017 |
| n.a. | Borealis | Midwest Fertilizer Co | Mt Vernon, IN | Nitric acid | 1,530 | CA | 2017 |
| Tecnimont | Stamicarbon | Midwest Fertilizer Co | Mt Vernon, IN | UAN | 4,300 | CA | 2017 |
| Black & Veatch | KBR, Casale | Koch Nitrogen | Enid, OK | Ammonia | 1,680 | RE | 2016 |
| Black & Veatch | Stamicarbon | Koch Nitrogen | Enid, OK | Urea | 2,200 | UC | 2016 |
| Linde | Linde | Simplot Phosphates | Rock Springs, WY | Ammonia | 600 | CA | 2016 |
| Casale | Casale | Rentech Nitrogen | East Dubuque, IL | Ammonia | 1,180 | RE | 2016 |
| n.a. | n.a. | Rentech Nitrogen | East Dubuque, IL | Nitric acid | +30 | RE | 2015 |
| n.a. | Casale | Summit Clean Energy | Pennwell, TX | Ammonia | n.a. | DE | n.a. |
| Casale | Casale | El Dorado Ammonia | El Dorado, AR | Ammonia | 1,210 | RE | 2016 |
| n.a. | Haldor Topsoe | BioNitrogen | Florida | Ammonia | 300 | DE | 2017 |
| n.a. | Haldor Topsoe | CHS | Spiritwood, ND | Ammonia | 2,200 | CA | 2018 |
| Tecnimont | KBR | Cronos Chemical | Tuscola, IL | Ammonia | 2,200 | CA | 2018 |
| Tecnimont | Stamicarbon | Cronos Chemical | Tuscola, IL | Urea | 3,850 | CA | 2018 |
| n.a. | n.a. | BASF/Yara | Freeport, TX | Ammonia | 2,270 | P | n.a. |
| **UKRAINE** | | | | | | | |
| Casale | Casale | Severodonetsk Azot | Severodonetsk | Urea | 1,600 | RE | 2015 |
| **UZBEKISTAN** | | | | | | | |
| Casale | Casale | OJSC Maxam Chirchiq | Chirchick | Ammonia | 1,500 | RE | 2015 |
| **VIETNAM** | | | | | | | |
| TEC, ThyssenKrupp | ThyssenKrupp I.S. | Vinacomin | Thai Binh | Nitric acid | 500 | UC | 2015 |
| TEC, ThyssenKrupp | ThyssenKrupp I.S. | Vinacomin | Thai Binh | Ammonium nitrate | 625 | UC | 2015 |

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# Reducing costs in large ammonia plants

During the last 50 years, KBR has successfully demonstrated the increase of the front end pressure of reforming from 27 bar(a) in the 1960s to 51 bar(a) in an ammonia plant that was commissioned in India in 2013. **A. Malhotra** and **U. Jain** of KBR discuss KBR's experience with high pressure reforming and how it can be incorporated in the design of large capacity ammonia plants to save energy and reduce the plant cost.

Natural gas feed stock is usually available at higher pressure and since reforming reactions result in a substantial increase in total volume, reduction in energy consumption per tonne of ammonia and equipment cost can be achieved by increasing the reforming pressure. KBR has been one of the leaders in increasing the reforming pressure, starting at about 27 bar(a) (measured at the inlet of primary reformer tubes) in the KBR designed ammonia plants commissioned in the 1960s rising to 38~39 bar(a) in ammonia plants commissioned in the 1980s, and increasing further to to 43~44 bar(a) in ammonia plants commissioned in the 1990s~2000s. KBR has designed or commissioned more than 25 ammonia plants using such high pressure. In April 2013, KBR successfully commissioned the NFL (National Fertilisers Limited) 950 t/d ammonia plant located at Nangal, Punjab, India. In this plant the pressure was increased to 51 bar(a).

## Primary reforming reaction

The basic reactions in the primary reforming of natural gas (assume methane) are:

$$CH_4 + H_2O = CO + 3H_2 \qquad \Delta H_{298} = +206.3 \text{ kJ/mol} \quad (1)$$

$$CO + H_2O = CO_2 + H_2 \qquad \Delta H_{298} = -41.2 \text{ kJ/mol} \quad (2)$$

Drivers for higher reforming pressure include:

- Reforming reactions result in increase in total volume and therefore significant savings of the compression energy used in synthesis gas and refrigeration compressors can be achieved if the reforming process is undertaken at elevated pressure. Overall energy consumption per tonne of ammonia produced can be reduced.
- Feedstock natural gas, in some locations, is available at elevated pressure.
- For large capacity single stream ammonia plants (>3,000 t/d), higher front-end pressure will reduce the size of equipment and piping.
- Higher front-end pressure results in higher temperature levels at which the heat of condensation of the excess steam after shift conversion can be recovered.

## Challenges of higher front-end pressure

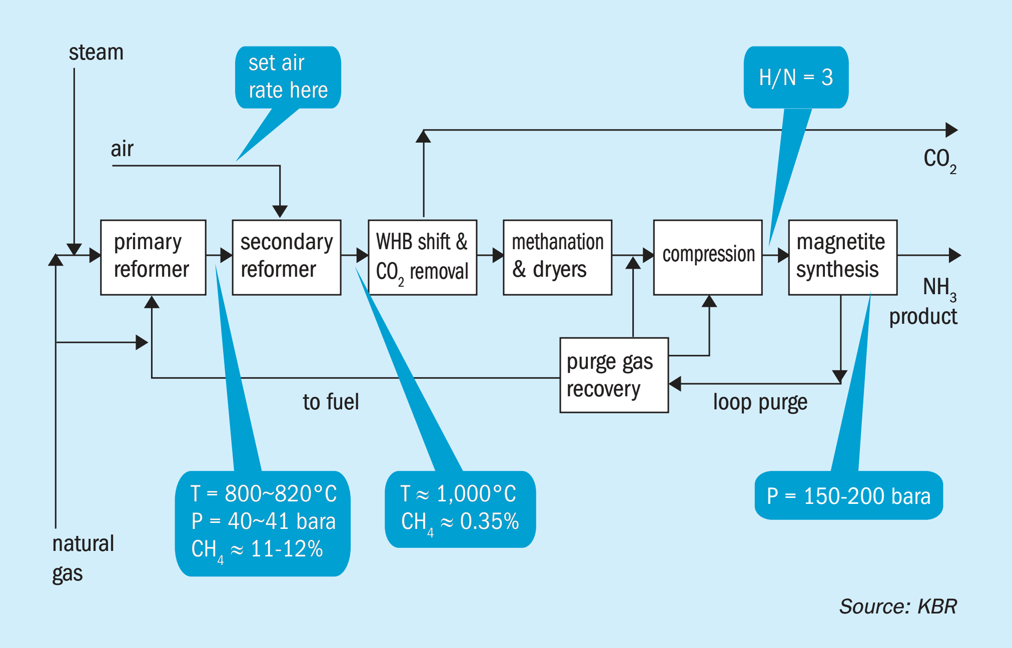
Higher pressure exerts an unfavourable effect on the equilibrium in equation (1) and therefore results in higher methane exit the primary reformer. An increase in heat duty to the primary reformer is required to decrease methane. However, the increase in heat duty is limited by the temperature exit the primary reformer.

This limit is about 800~820°C for operating temperature at the primary reformer exit pressure of 40~42 bar(a), depending upon the material of construction used for the primary reformer tubes and connected components.

However, the following options can be applied to reduce the heat duty of the primary reformer:

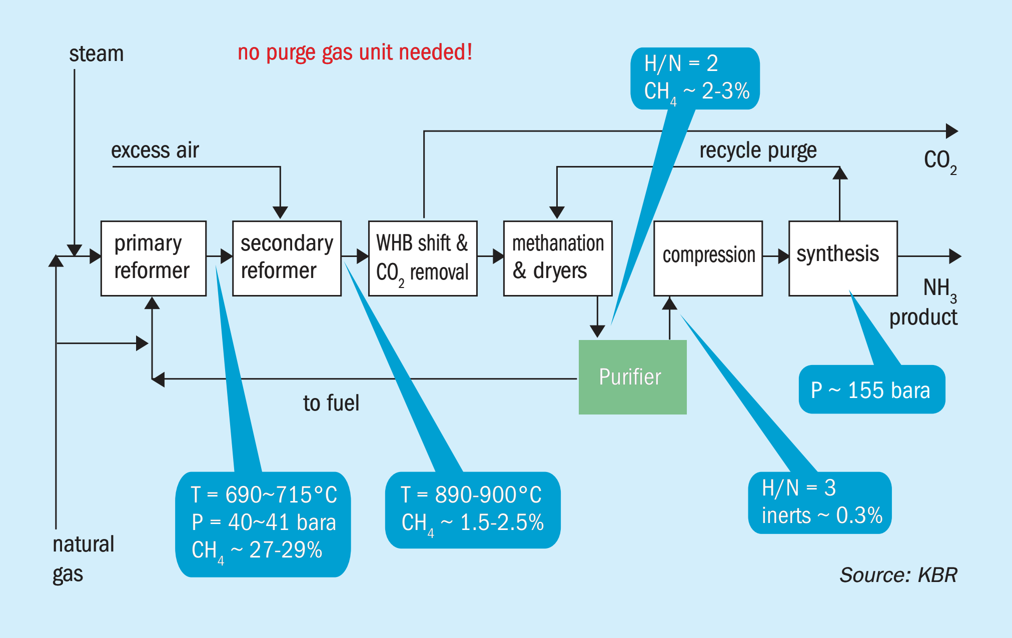
- The steam-carbon ratio to the primary reformer can be lowered by using a low energy and efficient $CO_2$ removal process. By using a MDEA based $CO_2$ removal process, the steam carbon ration can be decreased to 2.5~2.7.

Fig 1: **Block flow diagram for KBR conventional ammonia process**



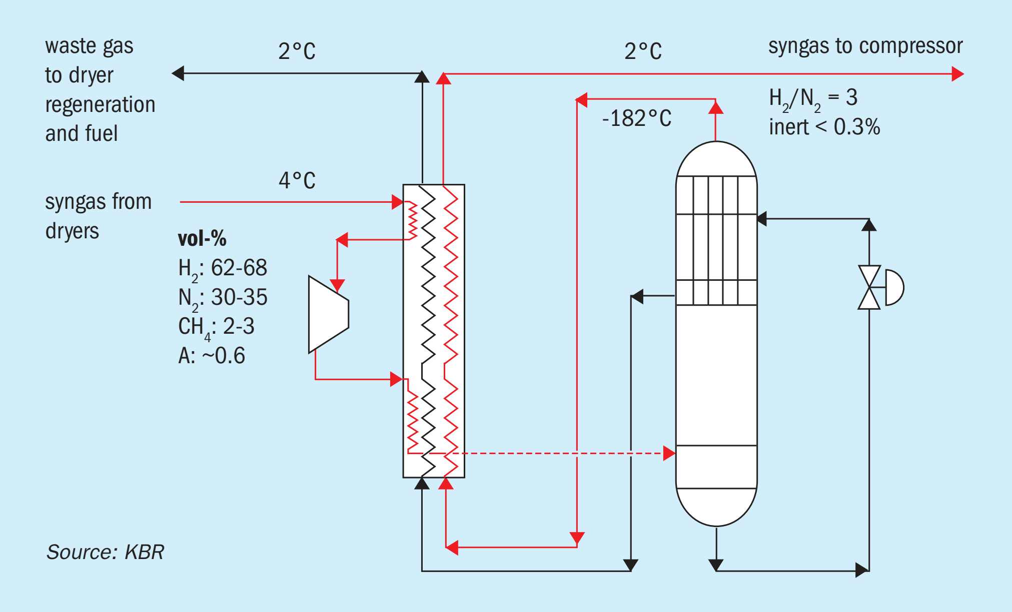
*Source: KBR*

Fig 2: **Block flow diagram for KBR Purifier™ ammonia process**



*Source: KBR*

Fig 3: **Sketch of KBR Purifier™**



*Source: KBR*

- Another option to reduce heat duty is to shift reforming duty from primary to secondary reforming. This is accomplished in KBR's Purifier™ ammonia technology. In this process almost 25~30 % of the primary reformer heat duty is shifted to secondary reforming by using excess process air. In this process, the temperature exit the primary reformer is reduced to 690~7150°C when the primary reformer exit pressure is 40~42 bar(a). This temperature is 105~110°C less than the maximum allowable operating temperature of 800~820°C. This option offers the greatest potential to increase reforming pressure.

With the commissioning of NFL's ammonia plant in 2013, KBR has demonstrated the successful operation of reforming at 51 bar(a) at the inlet of the primary reformer.

## Conventional process flowsheet

A block flow diagram of the KBR conventional (non-Purifier based) flowsheet is shown in Fig. 1. The process configuration consists of standard units for primary and secondary reforming, shift, $CO_2$ removal, methanation, synthesis loop and purge gas recovery. In this conventional flowsheet process air flow to the secondary reformer is set to achieve a H/N ratio of 3:1 in the makeup gas to the synthesis section. This results in very high temperature of process gas exit the primary reformer tubes and secondary reformer. This limit's the increase of pressure of the frontend of the ammonia plant.

## KBR's purifier process flowsheet

A block flow diagram of the KBR Purifier process is shown in Fig. 2. The process configuration consists of units for mild primary and secondary reforming, shift, $CO_2$ removal, methanation, Purifier (Fig. 3) and synthesis. No separate purge gas hydrogen recovery is required. In this flowsheet process air flow to the secondary reformer is set to achieve a H/N ratio of about 2:1 in the feed gas to the Purifier. About 30% of reforming is shifted from primary to secondary reforming. This results in a much lower (690~715°C) temperature of process gas exit the primary reformer tubes and also a lower temperature (880~900°C) exit the secondary reformer. The Purifier provides the makeup gas to the synthesis section with a H/N ratio of 3.0 and 0.25~0.30% inert. Most of the methane, excess nitrogen and some argon are removed as waste gas from the Purifier and are used as fuel in the primary reformer.

## NFL Nangal process

National Fertilisers Limited (NFL) has been operating a 950 t/d ammonia plant at Nangal, Punjab, India, since the 1970s, using fuel oil as feedstock. In this plant the front end of the ammonia plant was operating at 66 barg pressure using Shell's partial oxidation process.

In January 2010, NFL selected KBR ammonia technology to revamp the front end of the ammonia plant using NG/RLNG as feedstock. The synthesis loop remained unchanged. Tecnimont Spa Italy and Tecnimont-ICB India, were the EPC contractors for this project.

In order to minimise changes to the existing synthesis gas compressor and synthesis loop, KBR selected high pressure reforming using KBR Purifier™ ammonia technology. A brief process scheme follows.

### Feed gas compression, preheating and desulphurisation

Natural gas, after compression, is desulphurised in a standard hydrotreater (CoMox) and desulphuriser (ZnO) units producing an effluent stream containing less than 0.1 ppmv of sulphur.

### Primary reforming

Desulphurised feed gas is mixed with process steam to give a steam to organic carbon molar ratio of 2.7:1 and enters the

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primary reformer at 495°C and 51 bar(a).

The primary reformer effluent gas, at 724°C, contains about 29 mol-% (dry basis) of unreacted methane.

The Purifier process uses 50% excess air (than conventional process) in the secondary reformer. This feature reduces the size of the primary reformer furnace by about one third, and lowers the process gas outlet temperature from the reformer substantially, as compared to a conventional ammonia plant. The lower outlet temperature results in longer tube life and catalyst life.

## Secondary reforming

Hot compressed process air and primary reformer effluent are sent to the top section of the secondary reformer. KBR process does not use any metallic burner. Instead spontaneous combustion occurs in a non-metallic combustion chamber. The unreacted methane content in the gas leaving the secondary reformer is about 1.8~2.0 mol-% (dry basis). In this process there is no need to reduce methane lower (say to 0.3 %) since all the excess methane will be removed in the Purifier and returned as fuel to the primary reformer.

The heat in the secondary reformer effluent at a temperature of about 900°C is recovered by generating HP steam in the secondary reformer waste heat boiler. This is a KBR proprietary design. It is a vertical, water-tube, thermosyphon boiler. The tube bundle is removable.

## Shift conversion

The cooled secondary reformer effluent is sent to the two stage shift converters i.e. high temperature shift (HTS) and low temperature shift (LTS). Carbon monoxide content exit LTS is about 0.25 mol-% (dry basis). In the Purifier based ammonia plant, an increase of carbon monoxide exit LTS, due to catalyst aging, has little effect on the ammonia production. Increased carbon monoxide will be converted to methane, which will be removed in the Purifier and returned as fuel to the primary reformer.

## Carbon dioxide removal

The carbon dioxide removal unit uses a two stage OASE® process licensed by BASF.

It is worth noting that due to the use of excess air in the secondary reformer, the Purifier process generates proportionately more (~10% more) carbon dioxide than the conventional (non-purifier based) steam reforming processes. This reduces the amount of surplus syngas "wasted" to the fuel system, as compared to other conventional processes.

## Methanation and drying

The process gas from the $CO_2$ system is then sent through the methanation unit where residual carbon oxides are reduced to less than 5 ppmv (dry basis). The methanator effluent is cooled and chilled to about 4°C. The process condensate is removed and gas is then sent to the molecular sieve driers. There are two driers packed with zeolite based desiccant that operate cyclically. Each drier is sized to remove traces of ammonia, residual carbon dioxide, and water in a 24-hour drying cycle.

## Cryogenic purification

Dried raw synthesis gas is then sent to the cryogenic purification section. The gas is cooled by heat exchange with make-up synthesis gas and with Purifier waste gas in the top section of the Purifier feed/effluent exchanger. The gas then flows through the Purifier expander, where work is removed to provide the net refrigeration duty required for the Purifier. The expander energy is recovered by generating electricity in the Purifier expander generator. The expander effluent is further cooled and partially condensed in the bottom section of the Purifier feed/effluent exchanger and enters the Purifier rectifier at -171 °C. Liquid from the bottom of the rectifier is partially evaporated at reduced pressure in the shell side of the Purifier rectifier condenser and provides cooling for the condenser and reflux for the column.

The rectifier bottoms contain the excess nitrogen, most of the methane, and some of the inlet argon. The partially evaporated liquid leaving the shell side of the Purifier rectifier condenser is reheated and vaporised in the Purifier feed/effluent exchanger and leaves as Purifier waste gas. The waste gas is used as carrier gas to regenerate the molecular sieve driers and then sent to the fuel system.

The make-up syngas from the top of the Purifier rectifier condenser is reheated in the Purifier feed/effluent exchanger and sent to the existing synthesis gas compressor at 1.8°C. The operation of the Purifier is controlled by a hydrogen analyser on the synthesis gas, to maintain an exact molar ratio of hydrogen to nitrogen of 3:1. The only other impurities in the make-up synthesis gas are about 0.32 mol-% argon and less than 50 ppmv of methane.

## Syngas compression & synthesis loop

Most of the existing equipment has been used with much lower operating pressure.

### Purge gas ammonia recovery

The old synthesis loop did not have a purge gas recovery unit since pure synthesis make up gas was coming from a nitrogen wash unit. In the revamp configuration, the synthesis loop operates with 3.2 % inerts. Therefore a new unit to recover only ammonia from the small amount of purge gas from the synthesis loop is installed. Ammonia-free gas is recycled to up stream of the Purifier to recover hydrogen thereby eliminating the need for a separate purge gas hydrogen recovery unit.

Flash vapour from the ammonia letdown vessel is sent to the LP ammonia scrubber where it is scrubbed with water to recover most of the ammonia. The overhead from the LP ammonia scrubber is sent to the fuel system.

## Process condensate stripping

A process condensate stripping system is provided to strip dissolved carbon dioxide, methanol and ammonia from process condensate. The stripped condensate is sent to offsite for treatment in the polisher unit. The stripping medium for the process condensate stripper is process steam on its way to the primary reformer.

The steam leaving the stripper is mixed with the feed gas upstream of the primary reformer.

## Operating experience

The plant was revamped by KBR with a nameplate capacity of 950 t/d and achieved mechanical completion by mid February 2013. The primary reformer was lit up on 15th March 2013 and the Purifier was put in service on 10th April 2013. Ammonia production was achieved on the same day.

The catalyst used in the front end is:

| | |
|---|---|
| *Primary reformer* | ReforMax 210 LDP Top |
| | ReforMax 330 LDP Bot |
| *Secondary reformer* | ReforMax 400 GG Top |
| | ReforMax 410 LDP Bot |
| *HT shift* | Shift Max 120 |
| *LT shift* | LK 821-2 |
| | LSK2 |
| *Methanator* | Meth-134 |
| *Mol seives* | Z4-04 |

All above catalysts have performed as per specification at the higher front-end pressure operation.

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The plant had some teething problems as is expected in any commissioning. These were resolved and plant operation was stabilised and optimised.

The plant has since been operating successfully, consistently achieving ammonia production above 100% capacity. All operating parameters are well within design limits.

## Other design features

Although the front-end pressure was increased by about 8 bar it is interesting to note the following:

- The primary reformer tubes are 127 mm ID and have a thickness of 9 mm. The same size tubes have been used for the lower front end pressure case. The thickness of the tubes did not increase since the tube outlet temperature is still very low.
- All process piping in the front end is 600 # rating.
- Over reduction in HTS catalyst was not observed. In general since the Purifier™ process uses excess process air, the severity of the process gas in the HTS at certain steam:carbon ratio and pressure is roughly equivalent to the conventional process operated at a steam:carbon ratio 1.2 times higher.

## Large capacity ammonia plants

Higher front-end pressure is especially advantageous for single stream ammonia plant capacities 3,000 t/d and higher.

KBR recently designed and offered a 3,500 t/d ammonia plant with higher front-end pressure. Salient features of this design are:

- All static equipment in the plant are in a single stream
- All rotating equipment except semi-lean solution pumps in the $CO_2$ removal system are in a single stream
- Primary reformer is standard top fired KBR design with 336 tubes of 132 mm ID. No pre-reformer, reforming exchanger or high flux fired reformer has been used.
- One vertical, water-tube, thermo syphon secondary reformer waste heat boiler
- Only one KBR's standard cold wall horizontal three-bed ammonia converter – size 3.4 M ID & 33.4 M TTL
- One unitised chiller for 100% cold product
- All process piping in the synthesis loop is 24" size or less.

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3. Appl M., Modern Production Technologies, published by Nitrogen

## Acknowledgement

This article is based on the paper "High Pressure Reforming – KBR Experience" written by **Avinash Malhotra** and **Umesh Jain** of KBR and presented at the AIChE Ammonia Safety Symposium, 2014. ■

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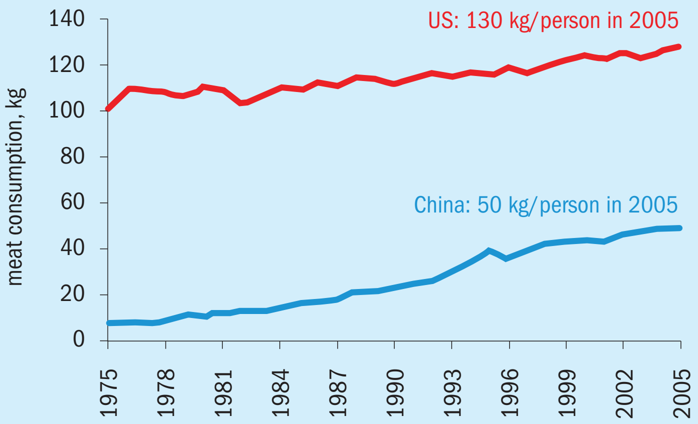
# Worldwide trends in urea process technologies

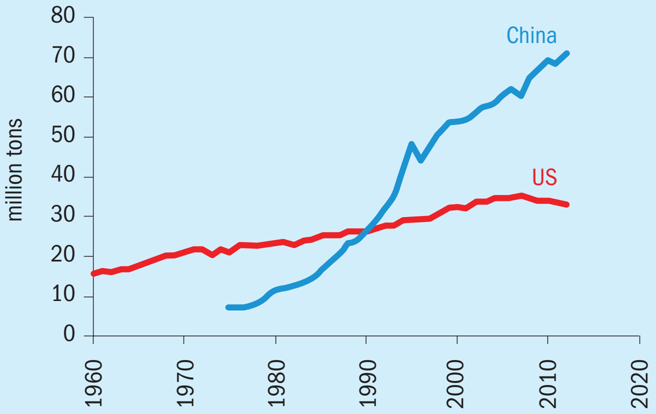
**J. Eijkenboom** and **M. Brouwer** of UreaKnowHow.com provide an overview of worldwide trends in urea process technologies including: market share, latest materials of construction, design capacities and final product selection.

Fig 1: **China's meat consumption per person** per year, kg



Source: USDA

Fig 2: **Meat consumption in China and US** 1960-2012



Source: USDA

Urea demand is booming as never before. Since the financial crisis in 2008 the number of new urea plants awarded annually has nearly doubled. The main drivers for urea consumption and new urea plants are:

- population growth;
- diet change in China;
- biofuels in the US, South America and Europe;
- AN regulations;
- food prices;
- monetising on natural gas resources;
- change over from gas to coal in China;
- shale gas revolution in US;
- politics.

The most significant drivers having the largest impact are currently: diet change in China, change-over from gas to coal in China and the exploration of shale gas in the US.

## Diet change in China

Economic progress in China has already led to the strong growth of meat consumption in China. However, despite the increase, meat consumption in China is still only 40% of meat consumption in the US (see Figs 1 and 2 for a comparison of meat consumption in China and the US).

Animal feed is a key driver for grain consumption. Beef requires 7 kg grain per kg beef, pork 4 kg grain per kg and poultry 2 kg grain per kg. As meat consumption per person in China is currently still significantly lower than for example in the US, it is expected that meat consumption will increase in the near future and more grain and more urea will be consumed. Meanwhile, the fertilizer application per hectare in China is already relatively high meaning that China will need to import meat and grain to fulfil this need. And this means that urea consumption outside China will be driven by this Chinese demand.

## Change over from natural gas to coal in China

China has a natural gas shortage and priority is given to power plants, which are located close to urban areas for environmental reasons. Coal is an important feedstock for power consumption and it has been the policy of the Chinese government that every new coal mine has to also construct a chemical or fertilizer plant in order to develop the local industry. As an ammonia/urea complex is relatively simple to construct, many new urea plants have been constructed, leading to an overcapacity of some 20 million t/a urea currently. This has led to pressure on natural gas based plants to close or relocate.

## Shale gas revolution in US

The US currently produces about 7% of the worldwide urea production. To date, the US has become a large importer of urea due to high gas prices. However, everybody knows that the drilling for shale gas has caused an industrial revolution in the US, leading to about 15 new urea prospects of which 8 are already under construction. It is expected that the import of urea to the US will end soon and the question is will the US become a urea exporter in the future?

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Fig 3: **Urea process technologies of existing urea plants**

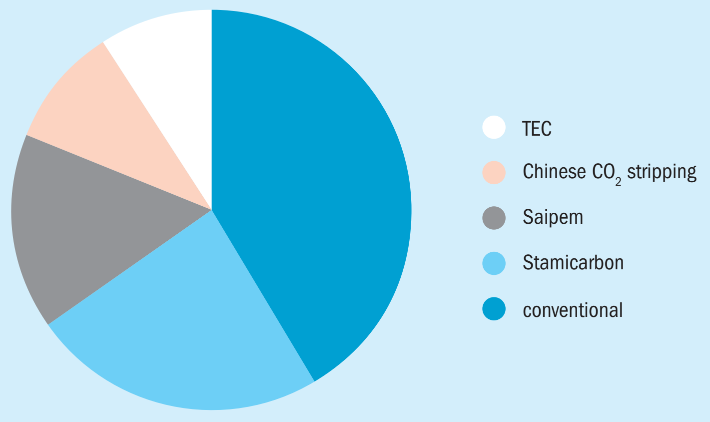
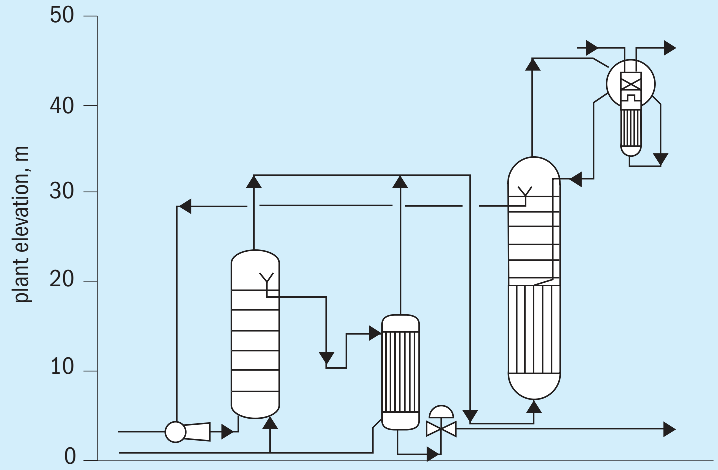


Fig 4: **THESES synthesis layout**



## Urea process technologies

Figure 3 shows the urea process technologies applied in the 510 urea plants currently in operation.

A significant number of these plants (42%) are still operating with conventional technologies, meaning urea technologies without a stripper. Most of these have a relatively high energy consumption and a relatively low capacity. These technologies include amongst others Stamicarbon, GIAP, TEC, Tecnimont, Chemico and Chinese technologies. 24% of the plants are based on Stamicarbon $CO_2$ stripping technology, 10% with Chinese $CO_2$ stripping technology, 16% Saipem $NH_3$ stripping technology and 9% TEC $CO_2$ stripping technology.

Nowadays China is very active in further developing its urea technology. For example Wuhan Engineering Corporation in Wuhan has developed a urea technology called "Technology of High Efficiency Synthesis and Energy Saving (THESES)", which is a combination of a vertical submerged condenser and a reactor together with a low elevation layout by means of a high pressure ejector. Figure 4 shows the layout for this synthesis section. This innovative technology is proven at 500 t/d since January 2014 at Meifeng in Sichuan.

## Worldwide trends in urea process technologies

Another example of innovative Chinese urea technology is the "JX Urea Technology" developed by the company JX in Chengdu, which is an improved conventional urea technology (so only a high pressure reactor as synthesis section) and realises consumption figures similar to the stripping technologies for a significantly lower investment figure. This technology is proven at 1,000 t/d since January 2009 and there are several references at 1,500 and 2,000 t/d. Figure 5 shows a DCS screen print of the synthesis section.

Fig 5: **DCS print of synthesis section of JX urea technology**

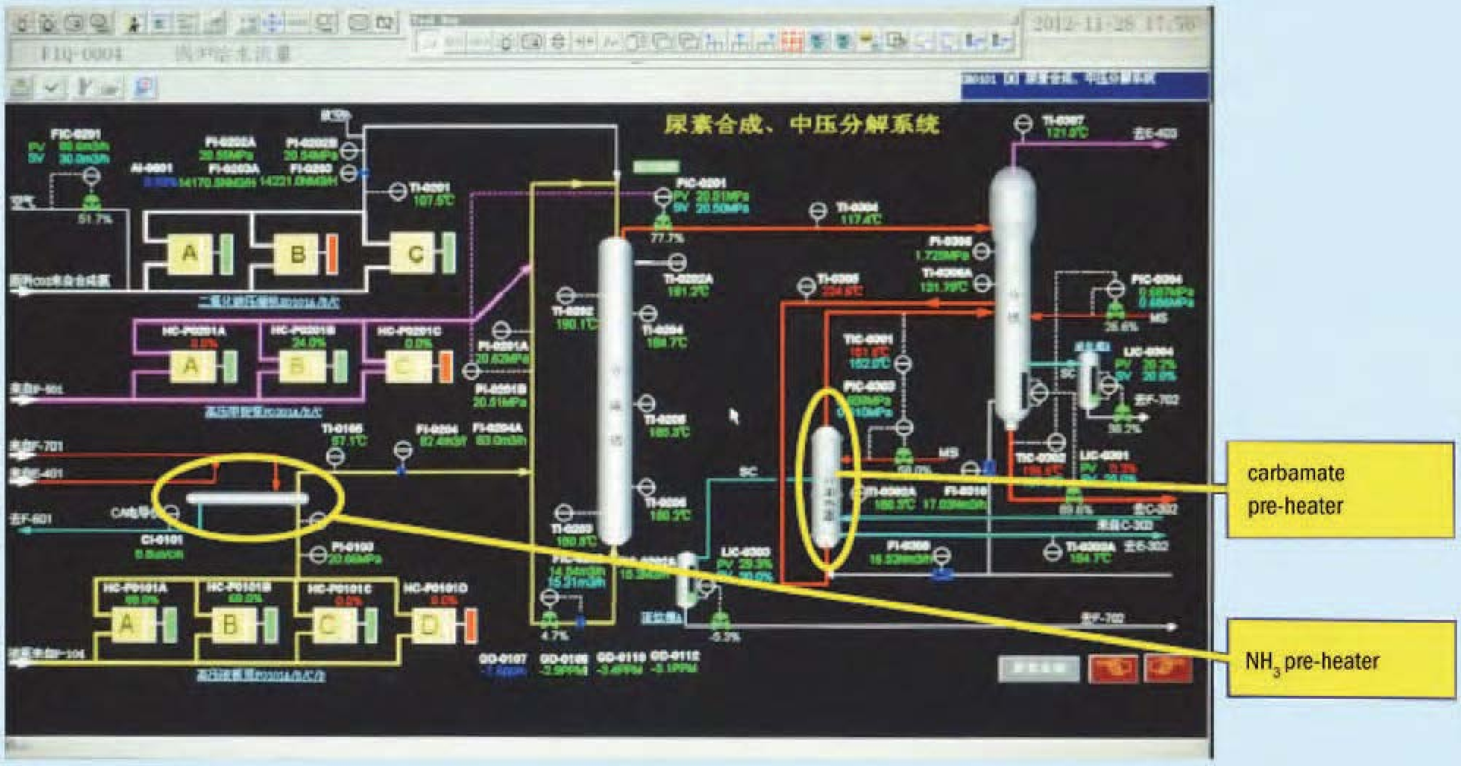


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Fig 6: **3,000+ t/d urea plants awarded during last two decades**

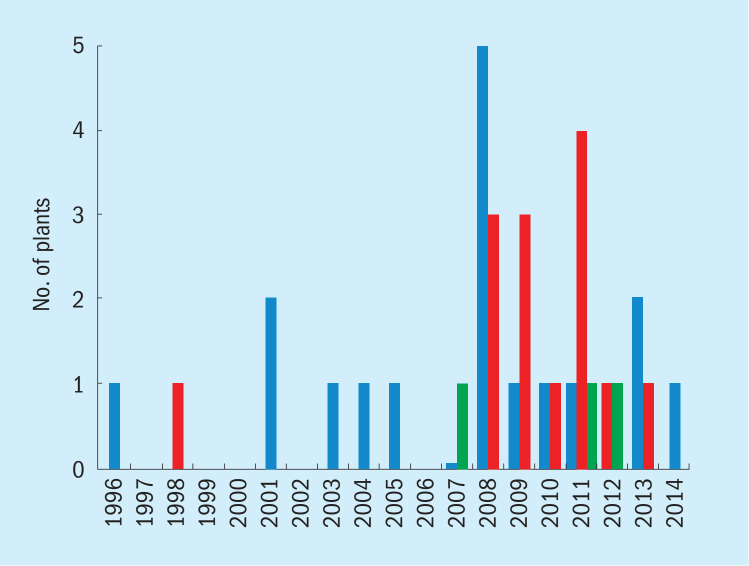
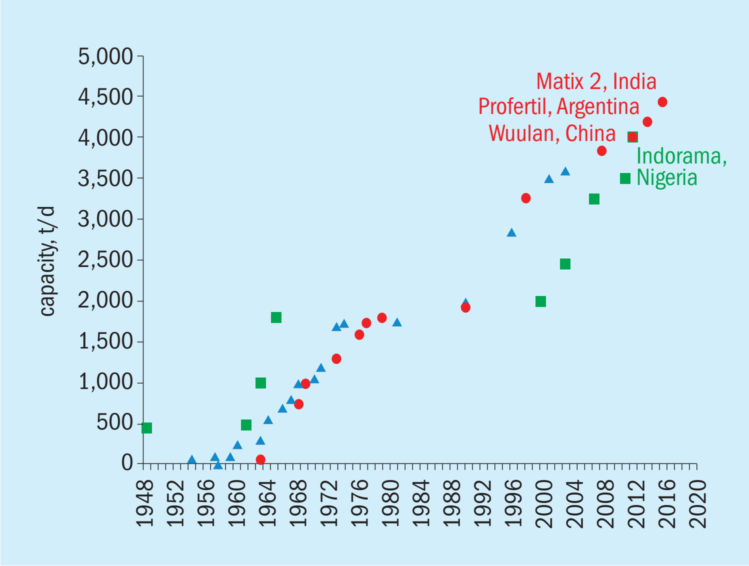


Fig 7: **Largest design capacity awarded in time**



## Mega urea plants

Figure 6 shows the number of 3,000+ t/d urea plants awarded so far by Stamicarbon (blue), Saipem (red) and TEC (green) during the last two decades. Before this period no 3,000+ t/d urea plants were in operation.

Mega urea plants (here defined as 3,000+ t/d) have clearly become more and more popular. The three major urea licensors Stamicarbon, Saipem and TEC are active and successful in this field. The other urea licensors are not yet active in mega urea plants although the Chinese $CO_2$ stripping technology is currently up to 2,700 t/d.

In total, Stamicarbon has been awarded 17 mega urea plants of which nine are in operation, Saipem has been awarded 15 mega urea plants of which six or seven are in operation and TEC has been awarded three MEGA urea plants of which one is in operation. All of these mega urea plants produce fluid bed granules except for Engro in Pakistan, Erdos in China and Matix in India, which produce prills.

## Trends in urea technologies

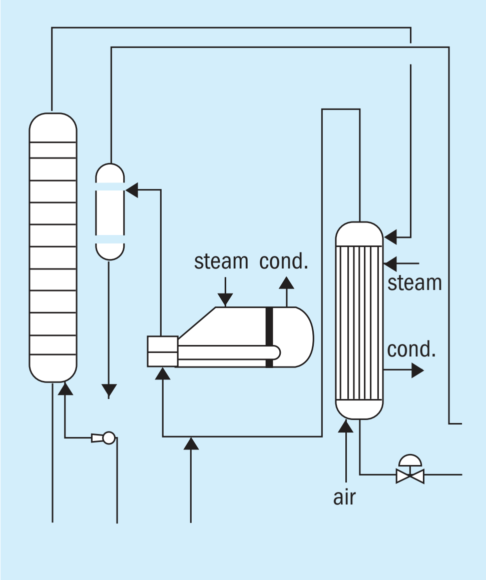
### Plants are getting larger

Figure 7 shows the largest design capacity of Stamicarbon (blue), Saipem (red) and TEC (green) urea plants awarded in a certain year. It shows that the design capacity of urea plants has been steadily increasing over time and all major urea licensors have been active in this field. Currently Saipem has 4,000+ t/d urea plants under construction in China (Wuulan) and Argentina (Profertil) and TEC has a 4,000+ t/d urea plant under construction in Nigeria (Indorama). Currently the planned Matix2 project in India seems likely to become the largest urea plant worldwide with 4,430 t/d design capacity, although there is some delay in the supply of the coal bed methane.

In addition, on several plants debottlenecking technologies have enabled licensors to achieve new maximum design capacities. Examples include: Yara Canada, a Stamicarbon licensed plant (originally 2,000 t/d, now running at 3,300 t/d), Profertil, a Saipem plant (originally 3,250 t/d, now debottlenecked to 4,200 t/d however actually operating at about 3,950 t/d), Erdos, a Stamicarbon plant (via a debottlenecking project from 2 x 1,000 t/d trains to a single train with a capacity of 3,520 t/d) and Sichuan Chemical Works, a TEC plant (via a debottlenecking project the ACES21 process has been proven at 2,460 t/d).

Economy of scale works apparently and one can expect the first 5,000+ t/d urea plant within the next five years. For example, if the Stamicarbon medium-pressure add-on debottlenecking technology were to be applied in one of the Stamicarbon mega urea plants, the capacity would already reach 5,000+ t/d urea.

Fig 8: **Layout of Saipem synthesis section**



### Lower elevation of urea synthesis section

In order to minimise investment costs all licensors have developed technologies with a lower elevation of the urea synthesis section. Saipem and TEC apply a high pressure ejector, while Stamicarbon in their Avancore process can still rely on gravity (see Figs 8-10).

### Submerged condensation in synthesis section

Submerged condensation has several benefits:

- more efficient condensation (heat transfer coefficient of submerged condensation is 40% higher than that of falling film condensation);
- as residence time is available for carbamate at high temperatures,urea conversion takes place leading to a higher LMTD in the condenser;
- easier and more and stable operation as the submerged condenser acts as a buffer for fluctuations in, for example, the N/C ratio.

Stamicarbon introduced submerged condensation in the synthesis section in 1996 with the pool condenser and TEC followed with the vertical submerged carbamate condenser (VSCC). Later Casale introduced a revamp scheme changing a falling film high pressure carbamate condenser into a submerged type called the full condenser.

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15 SAFETY IN AMMONIA PLANTS & RELATED FACILITIES SYMPOSIUM

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Fig 9: **Layout of TEC ACES21 synthesis section**

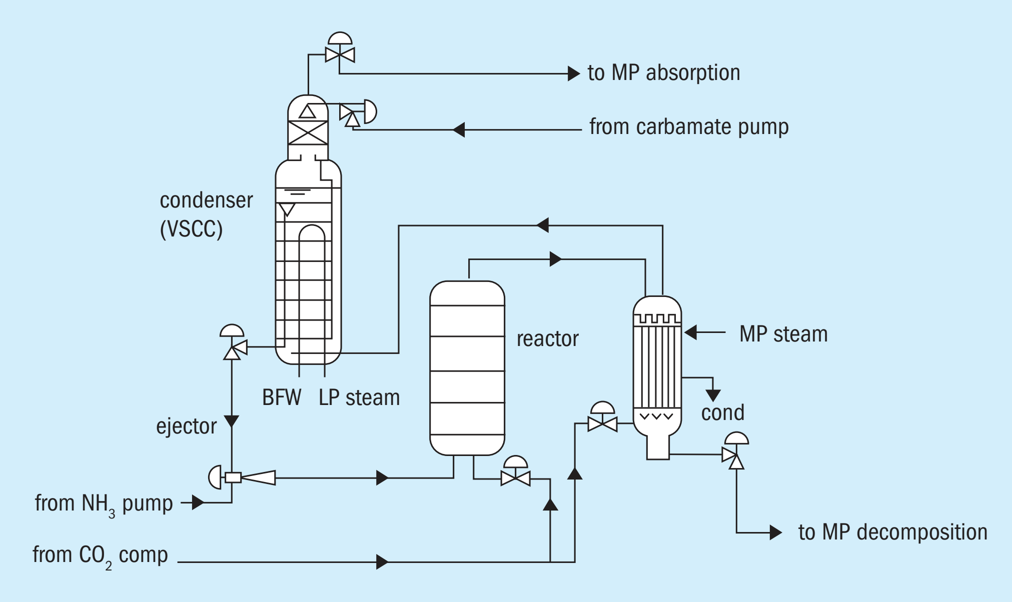
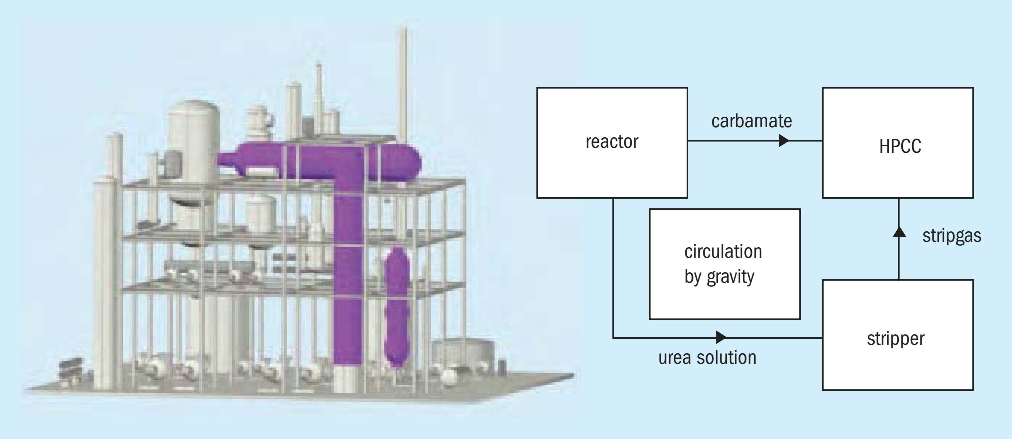


Fig 10: **Layout of Stamicrbon Avancore synthesis section**



## Lower emissions

Existing and new urea plants are increasing facing more stringent emission requirements. For example:

- All urea plants (including existing ones) in Saudi Arabia have recently implemented acid washing to minimise $NH_3$ emissions from prilling towers and granulation plants. Note: Permit emission levels in existing urea plants are typically not challenged.
- Environmental permits for new plants in the US are very strict (up to 10 ppm $NH_3$ and urea dust and discussions about opacity).
- Flares are standard nowadays although flares are more a safety than environmental measure.
- Lower emissions from e.g. prilling towers are in some cases realised in combination with the Sandvik Process Systems Rotoform technology to produce specialties (technical urea, AdBlue or Urea+AS).

## Higher alloys

Another interesting trend in urea process technologies is the development and implementation of higher alloy materials with higher corrosion resistance.

Stamicarbon and TEC have developed super duplex materials for their high pressure synthesis section respectively called Safurex® and DP28W™. More than 25 Stamicarbon urea plants operate with a synthesis section completely in Safurex®. Two TEC urea plants are in operation with all the high pressure equipment items from DP28W™. These higher alloy materials provide many benefits such as higher strength, lower wall thickness, less oxygen required and they are not sensitive for chloride stress corrosion cracking.

Saipem recently developed OmegaBond™ $NH_3$ stripper technology, in which the heat exchanger tubes of the stripper are made from a combination of zirconium (tube inside) and titanium on the outside and nowadays 25-22-2 austenitic stainless steel is used for the high pressure carbamate condenser and reactor.

Currently two OmegaBond™ strippers are in operation, the first one was installed at GPIC, Bahrain in 2009 and the second one was installed at FFC, Pakistan. Both OmegaBond™ strippers have already been inspected during a turnaround, Another advantage of using Omega Bond heat exchanger tubes is that the stripper bottom operating temperature can be increased to 208°C, and maybe even to 212°C.

Applying higher alloy materials leads to improved reliability and higher safety standards, resulting in higher on stream times.

## Multi-nutrient urea products/ higher nitrogen efficiency

The nitrogen efficiency when applying urea is only about 60-70%, which means that 30-40% of the nitrogen produced and applied does not reach the crop and is lost to air and water. This is a huge economic loss and environmental burden. However, there is a growing trend for urea plants to produce multinutrient urea products and/or urea products realising higher nitrogen efficiency.

For example Yara, SKW in Germany and Abu Qir Fertilizers in Egypt produce multi-nutrient urea products like urea + sulphur, urea + ammonium sulphate, urea + magnesiumsulphate etc. The Sandvik Rotoform technology is ideally suited to produce these multi-nutrient urea products.

Others produce urea products with a higher nitrogen efficiency like ESN of Agrium and several Indian urea producers like NFL, GNFC, TATA, IndoGulf, etc., who produce neem-coated urea. Neem-coated urea products are a simple and effective way to produce urea products with a higher nitrogen efficiency.

Also noteworthy is Virtual Fertilizer Research Center (VFRC), a research initiative that fosters the creation of the next generation of fertilizers and production technologies to help feed the world's growing population and provide sustainable increases in global food production, and this global issue requires a global solution. VFRC comprises the work of multiple research institutions around the world cooperating to advance a unified research agenda. ■

## Acknowledgement

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# Common causes of catalyst failure

Selecting the right catalyst has a significant impact on a plant's ability to continue operation through an unplanned event, which could be caused by transient conditions such as unusual mechanical forces, rapidly changing temperature, pressures or compositional changes. These challenges can lead to catalyst failures if the catalyst quality does not live up to expectations.

Several catalysts are used in the synthesis gas industry, covering the production of ammonia, hydrogen, methanol and other associated products, and the types vary from plant to plant.

With the exception of the ammonia synthesis catalyst, catalysts used in syngas plants are mainly fabricated as tablets and extrudates with mechanical properties similar to those of ceramics. Just as ceramics, catalysts used in syngas plants are produced with the objective to obtain a highly porous structure with an optimised pore distribution. Solid catalysts work in a reactive atmosphere, where it is necessary to balance properties for fluid flow, activity, and stability. Good flow distribution and low pressure drop are among the key process requirements for a catalyst, and are achieved by proper design of size and shape of the catalyst pellets.

The number of catalysts each plant employs mainly depends upon the feed type, process steps, plant designer and expected concentration and types of poisons in the feed etc. Depending upon the process conditions of each catalytic reactor, the physiochemical properties of each selected catalyst also vary. In other words, catalysts are designed for the most severe conditions that can be expected in the respective reactor. For example, secondary reformer catalysts are calcined to very high temperatures, much higher than the maximum temperature expected in the secondary reformer during production. The temperature is much higher than that of the primary reformer in an ammonia plant.

However, it is generally suggested that every catalyst should be operated at the lowest possible temperature that will allow economic conversion of the reactants to the desired products. This also usually ensures that thermal sintering or active metal crystallite growth is minimised. Over the useful life of the catalyst, plant operators may increase the operating temperature to maintain catalyst activity and achieve satisfactory conversion, which is also influenced by the plant load from time to time.

Catalyst deactivation, i.e. the loss over time of catalytic activity and/or selectivity, is typically a well-controlled process that occurs slowly. However, process upsets, hardware related issues or poor loading methods can bring about catastrophic failures in the plants. Since costs related to process shutdown and catalyst replacement amounts to a total of billions of dollars per year in the industry, catalyst deactivation is an issue of great and continuing concern for plant owners and operators.

Table 1: **Common catalyst failures**

| Mechanisms | Type | Description |
|---|---|---|
| Poisoning | Chemical | Chemisorption or bulk adsorption of species on catalytic sites, blocking for catalytic reaction |
| Fouling | Mechanical | Physical deposition of species on the catalytic surface and in catalyst pores |
| Thermal degradation | Thermal | Thermally induced sintering of catalytic surface area |
| Attrition/crushing | Mechanical | Loss of catalytic material or internal surface area due to mechanical failure/crushing of the catalyst particle |

A slow and well-controlled catalyst deactivation over time is unavoidable for most processes. However some of the immediate and drastic consequences of catalyst failure may be avoided, postponed, or even reversed. There are many paths for catalyst failure, and many mechanisms of catalyst deactivation. Some of the most common catalyst failures are described in Table 1.

Catalyst activity is mainly lost due to sintering and/or poisoning. Poisoning may result in temporary activity loss or permanent deactivation depending upon the mechanism.

In addition to catalyst stability, high mechanical integrity of the syngas catalysts is very important for reliable performance of a fixed bed reactor. In many industrial applications, mechanical and physical failure of the catalyst is more often the cause of process shutdowns and catalyst replacements than loss of activity.

The pressure applied can also influence the reaction rate depending upon the number of molecules participating and/or produced over the reaction. In extreme cases, very large operational pressure variation can literally explode the catalyst bed and individual catalyst particles.

It is better to operate the plant in the smoothest possible way to limit pressure variations. Standard operating variable changes recommended and usually accepted are:

- Pressure increase/decrease: max. 50% pressure change in 15 min
- Temperature increase/decrease: max. 50°C/hour

Pressure drop or pressure differences caused by the catalyst packed bed along with inert layering can also have a huge

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impact on plant flexibility and economics. All plant designers, process technologists and catalyst suppliers continue to improve the reactor configuration and catalyst activity and selectivity in order to minimise the energy loss due to pressure drop. At the same time there is also a certain minimum linear velocity and pressure drop that is required to have uniform flow through the reactor bed.

On the whole, within the synthesis gas industries there are very few cases of spontaneous catalyst failures during normal operation. Those that do occur tend to be due to one of two causes:

- The incorrect design or choice of catalyst bed ancillaries such as hold down media, support balls or grids.
- Operation outside of accepted parameters such as the wrong temperature, an incorrect feed gas composition or the presence of high levels of poisons.

There are occasional failures of catalysts due to quality control issues during catalyst production or the commercialisation of new catalysts. Both of these are outside the control of the plant operator and fall clearly with the catalyst manufacturer and the prevalence of such failures is certainly less than many decades ago.

## Johnson Matthey experiences

Johnson Matthey's experience is that there remains a steady rate of catalyst failures within synthesis gas plants. The majority of these do not occur during normal plant operation, but during what may be described as transient operating conditions. This encompasses a number of events, both planned and unplanned such as catalyst reduction, start-up, shutdown, trips and minor equipment failures (e.g. waste heat boiler leaks or minor cracking of secondary reformer burners). Minor equipment failures cover items which are common occurrences and should be survivable by the catalyst and not require immediate plant shutdown.

Over the past 11 years, Johnson Matthey has presented a number of papers on catalyst failures during plant operation. Most of these failures occurred during transient operating conditions rather than during the course of normal steady state operation.

An analysis of the failures described in some of the papers shows that, of the 35 catalyst failures described, 10 have been failures during what could be described as normal operation, with the remaining 25 (71% of all cases) failures occurring during transient operations. The 25 failures have been broken down by transient operation in Table 2.

Table 2: **Breakdown of catalyst failures during transient operations**

| Transient operation | No. of catalyst failures |
|---|---|
| Catalyst charging | 2 |
| Catalyst reduction | 3 |
| Start-up | 10 |
| Shutdown | 4 |
| Trip | 1 |
| Restart | 1 |
| Rate change | 1 |
| Minor equipment failure | 3 |

This is not an exhaustive analysis, but does provide some evidence for the view that transient operating conditions are the cause of the majority of catalyst failures. Whilst these events have typically occurred due to unexpected or unforeseen events or direct maloperation, they clearly indicate the need for the catalyst manufacturers to cater for transient conditions as far as is practicable.

Transient conditions during start-up, shutdown and unplanned events, can present some of the most difficult and challenging scenarios for process plant operations. Such conditions also place additional demands on the catalysts on which the process depends. These can include increased mechanical forces, rapidly changing temperatures and pressures or compositional changes all of which must be managed without lasting detriment to the catalyst or equipment. Often, the need to design the catalyst to cater for transient operation can be in direct conflict with the requirements of maximising activity during normal steady state operation.

In the following sections, Johnson Matthey provides examples where improved catalyst formulation has reduced or eliminated the losses associated with transient operating events.

### Steam reforming

Given the severe conditions under which a steam reforming catalyst has to operate, it is somewhat surprising that there are relatively few instances of catalyst damage during transient conditions.

To some extent this must be an indication of the robustness of steam reforming catalysts and the attention given to operation of the primary reformer based on the knowledge that deviation from normal operating conditions could result in significant damage to the furnace hardware itself.

There are a number of specific concerns that need to be faced during the development of steam reforming catalysts in terms of transient operation. In fact, within the primary reformer, these periods of transient operation exceed the requirements of the catalyst during normal operation in many cases. It has been by focusing on these areas during catalyst development that Johnson Matthey now has the rugged catalysts currently operated within the industry.

**Carbon formation**

All hydrocarbons will spontaneously decompose into carbon and hydrogen through the process of thermal and/or catalytic cracking reactions (equations 1, 2 and 3) at elevated temperatures.

$$CH_4 \leftrightarrow C + 2H_2 \qquad (1)$$

$$C_2H_6 \rightarrow 2C + 3H_2 \qquad (2)$$

$$CnH_2n+2 \rightarrow nC + (n+1)H_2 \qquad (3)$$

Any carbon that is formed is gasified by the carbon removal reactions (equations 4 and 5), which for typical steam reforming conditions are always on the carbon free side of equilibrium.

$$C + H_2O \rightarrow CO + H_2 \qquad (4)$$

$$C + CO_2 \rightarrow 2CO \qquad (5)$$

Carbon deposition on the catalyst only happens in practice when the carbon formation rates are higher than the carbon removal rates. In general, carbon formation is more likely to occur with forcing conditions such as heavier feeds, lower steam to carbon ratio and in high heat flux top fired reformers.

To cope with these forcing conditions, promoters are incorporated into steam reforming catalysts which depress the rate of carbon formation and promote the rate of carbon gasification. The most commonly used promoter is potassium. The potassium is incorporated in well-defined mineral phases which deliver the carbon gasification effect appropriate to the nature of the feedstock and operating conditions.

The potassium is associated with aluminium (as a stable potassium aluminate), which forms stable reservoirs of potassium within the ceramic structure of the pellet, able to deliver protection from carbon throughout the catalysts lifetime.

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Whilst the addition of potassium promoters to the catalyst is generally regarded as being a solution for the prevention of carbon formation during normal operation, they can also have a significant impact upon the catalysts ability to withstand transient operation. Such transient conditions fall primarily into two categories, firstly a lower than normal steam ratio or a heavier than normal feedstock or secondly the passing of hydrocarbon into a hot reformer without steam during start-up or shutdown.

An example where the use of KATALCO$_{JM}$ 47-4 and 25-4Q potassium promoted catalysts aided in the recovery from a heavier than normal feed is discussed below. In this ammonia plant some hydrocarbon condensate became trapped in the feed line. This was inadvertently passed into the primary reformer resulting in a lower steam ratio and the generation of hot bands on the tubes. The carbon formation also caused an increase in steam reformer pressure drop from 3.6 bar to 5.0 bar.

The carbon that had been formed, whilst detrimental to the performance of the plant and the tube wall temperatures, was not so bad that it required an immediate halt to production for a steam out. Without the presence of the potassium promoter, the carbon formation would have been very severe and would have required an immediate halt to production. As the plant needed to keep running it was decided to run at a slightly higher steam to carbon ratio.

Over the following two months of continued operation the catalyst recovered from the carbon incident. The pressure drop decreased by 0.3 bar and both the size and the temperature of the hot bands decreased, with a reduction of 20 to 30°C being observed.

This demonstrated that once the primary reformer returned to normal conditions, the carbon gasification rate was higher than the carbon formation rate and the carbon was being slowly removed.

The plant tripped after two months running at the increased steam to carbon ratio due to an unrelated issue. When the plant was restarted the opportunity was taken to carry out an extended steaming prior to re-introduction of feedstock. When normal operation was achieved the hot bands had disappeared and the primary reformer was returned to the normal steam ratio and the pressure drop returned to 3.8 bar, just above normal showing that the majority of the carbon had been removed and any catalyst breakage was minimal.

The second case where carbon can be formed is when hydrocarbon is introduced into hot dry reforming catalyst during start-up or shutdown and is a particularly troublesome transient event.

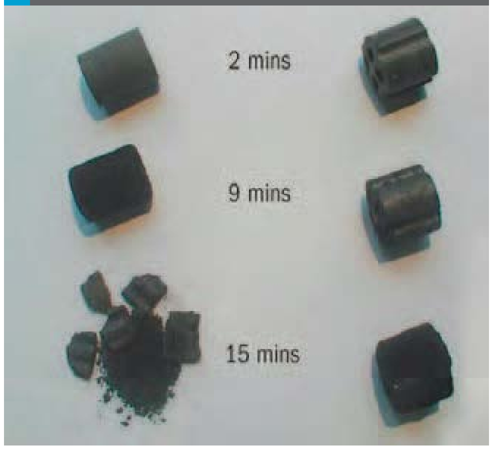
When carbon forms during normal operation or during a low steam ratio event the carbon tends to form on the outside of the catalyst pellets or on the inside tube walls as these surfaces see the highest concentration of hydrocarbon. This tends to leave the catalyst itself unbroken with little permanent damage as illustrated in the example above.

However, when hydrocarbon enters a hot dry reforming catalyst the carbon can form within the pore structure of the catalyst as there are no reforming reactions taking place to reduce the hydrocarbon concentration. This means that the carbon that is formed can generate enough internal pressure within the pellets to break the pellets apart. The presence of potassium may help to reduce the rate of carbon formation, but it will still form. Therefore, the only measure available is to design the catalyst pellet to have a high strength to minimise the breakage that results.

To illustrate this, a laboratory experiment has been carried out to simulate what happens when hydrocarbon alone is passed over the catalyst.

Robustness to carbon formation is shown through a test conducted on KATALCO$_{JM}$ 46-3 and KATALCO$_{JM}$ 46-3Q (Fig. 1). Reduced samples were exposed to cyclohexane and steam at 500°C. When test conditions were stable, steam flow was stopped and cyclohexane continued for set periods of time followed by inspection of the catalyst. The well proven KATALCO$_{JM}$ 46-3 had disintegrated after a 15 minute test whereas KATALCO$_{JM}$ 46-3Q retained its physical integrity and approximately 80 % of its strength.

Fig 1: **KATALCO$_{JM}$ 46-3 and 46-3Q exposed to pure cyclohexane**



Whilst long term flow of dry hydrocarbons into a reformer will result in the need to replace the catalyst, the experiment highlights that effective catalyst design can reduce these impacts and provide a greater safety net against this type of transient event. With better catalysts minor incidents of hydrocarbon only feed can better be tolerated.

An example of this is a hydrogen plant operating on a naphtha feedstock. This plant started up with an older type of naphtha reforming catalyst and during the first 30 days of operation suffered a series of trips and restarts. This resulted in hot spots developing on the reformer tubes as well as a high pressure drop over the steam reformer.

The reformer tubes were opened and a sample of catalyst was discharged and inspected. It was found that the operational problems detailed above were due to severe breakage of the catalyst one-third of the way down the tube and a significant quantity of powder and broken catalyst was found. This was due to a combination of carbon formation and thermal cycles.

As a result of all these, the plant was shut down for over six months and the decision was made to re-charge the reformer with KATALCO$_{JM}$ 46-3Q over KATALCO$_{JM}$ 46-6Q. The charge started up well, and despite less than perfect operation on the reformer in terms of continued un-steady operation the newer catalysts continue to operate well after more than 18 months on line.

There are also many examples of steam reformers operating on natural gas where the upstream gas processing plant is less than reliable. In these cases, a small amount of naphtha catalyst of type KATALCO$_{JM}$ 46-3Q in the top of the tube allows continued operation without forming carbon when slugs of natural gas liquids are passed forward from the gas processing plant.

## Secondary reforming

As with steam reforming, the catalyst in the secondary reformer is subjected to very high temperatures. In normal operation the conditions at the top of the bed, even with a uniformly mixed stream from the burner are above the vaporisation temperature for nickel and alumina, thus migration of the catalyst will always occur to some extent. However, the catalyst can be subjected to even higher temperatures, above the melting point of alumina during

Fig 2: **Vaporised catalyst**

Fig 3: **$\text{KATALCO}_{\text{JM}}$ 94-1 target tiles exposed to high temperature**

Fig 4: **$\text{KATALCO}_{\text{JM}}$ 89-6 catalyst exposed to high temperature**

extreme transient maloperation, or during burner failure.

Whilst examples of severe catalyst damage during transient events are known and have been reported, as with the steam reformer, they are relatively infrequent, most probably due to the controls and systems in place to maintain safe secondary reformer operation.

**Catalyst vaporisation**

Cracking of secondary reformer burners is a common finding during inspection and this often results in poorer mixing within the combustion chamber and overheating of areas of the catalyst bed. This typically results in vaporisation of the target tiles or lumps on the top of the catalyst bed along with the top 0.3m (1ft) of the catalyst bed in the regions of high temperature. The majority of the target tiles and catalyst bed remain in good condition.

It is possible to formulate the target tiles and catalyst support from zirconia rather than alumina.

Zirconia has a higher thermal stability than alumina or aluminate catalysts in terms of its melting point and its vapour pressure. Therefore, such tiles and catalysts are more resistant to the problems caused by burner cracking and overheating, which are typically seen as vaporisation and loss of material from the surface or softening and deformation of the material.

An example of the effect of poor burner mixing in an ammonia plant is shown in Fig. 2 for standard alumina target tiles and catalysts. In this case both the tiles and the catalyst have been badly vaporised in the part of the bed affected by the higher than normal gas temperature.

However, when exposed to equivalent conditions of higher than normal gas temperature over a period of 3 to 4 years, the $\text{KATALCO}_{\text{JM}}$ 94-1 target tiles and $\text{KATALCO}_{\text{JM}}$ 89-6 catalyst based on stabilised zirconia are unaffected and remain close to as new condition (Figs 3 and 4).

**Catalyst fouling**

In extreme cases of burner damage parts of the burner can fall away or are burnt away exposing large holes, which can give rise to flame impingement on the refractory. In this case, some of the refractory is vaporised, which then condenses out on contact with the cooler catalyst bed. The catalyst is substantially cooler than the gas due to the endothermic reaction. This often results in rapid pressure drop build up within the catalyst bed. A similar fouling can occur if the catalyst in the steam reformer breaks down and dust is blown into the secondary reformer. This dust passes through the flame region and is vaporised by the high temperature, before condensing on the cooler catalyst.

An example of the benefits of improved catalysts is in one of the first secondary reformers charged with the $\text{KATALCO}_{\text{JM}}$ 89-6 catalyst. This was a methanol plant with an oxygen fired secondary reformer and there was a partial charge of the high stability catalyst for test purposes to demonstrate its improved resistance to high temperature.

There was a carbon formation incident on the primary reformer when natural gas was inadvertently purged through the reformer after a trip whilst the reformer was still hot without any steam. This resulted in some breakage of the primary reformer catalyst, which was then blown into the secondary reformer on plant restart, which resulted in an increase in the secondary reformer pressure drop.

When the plant was shut down and the catalyst removed for inspection it was found that the primary reformer catalyst that had passed into the secondary reformer had as expected fouled the catalyst bed. It is believed that standard alumina type catalysts form a sticky surface during operation by combining with traces of sodium and/or silica to form lower melting point materials such as glasses, which subsequently adheres to the surface.

However, it was noted that although it had fouled the standard nickel on alumina catalyst (Fig. 5) it had not fouled the $\text{KATALCO}_{\text{JM}}$ 89-6 catalyst, which provides a less sticky surface than conventional alumina catalysts. The presence of rubies can also be seen on the alumina catalyst, a common occurrence during condensation of alumina vapour.

## High temperature shift

Compared to steam reforming and secondary reforming catalysts, the high temperature shift (HTS) catalyst operates at a relatively modest temperature. However, the HTS catalyst is much less robust than steam reforming catalysts and can be damaged through transient conditions such as wetting from upstream heat exchanger leaks.

**Catalyst wetting**

The wetting of HTS catalysts due to leaks in the upstream waste heat boiler (WHB) is a well known and common occurrence in ammonia plants, especially in ones with an aged waste heat boiler.

Fig 5: **$\text{KATALCO}_{\text{JM}}$ 89-6 in clean condition alongside alumina catalyst after fouling incident**

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Therefore, the HTS catalyst should be designed to withstand occasional wetting from this transient operating condition because it is a foreseeable event.

On a simplistic level, the development of a catalyst with maximum strength may be seen as the best mitigation against catalyst wetting. Maximising strength may be an important factor where the HTS catalyst is being fouled by a small continuous WHB leak and the pressure drop is building up as this will avoid pellet deformation and breakage.

However, in response to a sudden wetting from a larger WHB leak, maximum strength, whilst being a distinct advantage is not the most important aspect of the catalyst design. In this case, the dry out following the wetting is the main cause of catalyst failure and the catalyst must be able to withstand this transient condition. A catalyst that is designed to handle wetting and drying operations will have a high physical strength combined with an open pore structure. This allows easy egress of steam from the pellet during dry out, which reduces the internal hydraulic pressures and minimises the risk of pellet breakage.

An example of this is a plant that suffered a full bore leak in one of the WHB tubes. The HTS reactor was charged with $\text{KATALCO}_{\text{JM}}$ 71-6, a catalyst with an open pore structure designed for use in highly stressed ammonia plants. During the short period of operation after the leak developed and during the plant trip the HTS catalyst was completely wetted. After the WHB leak was repaired, the HTS catalyst was dried out and returned to normal operation. Upon return to normal operation the temperature profile before and after the wetting incident were the same (Fig. 6) as was the pressure drop at 0.13 bar.

## Low temperature shift

As with the HTS catalyst, the low temperature shift (LTS) catalyst operates at a relatively mild temperature, and may therefore be thought of as being more secure. However, the LTS catalyst is less robust than steam reforming catalysts as it has been designed to offer maximum activity at low temperature conditions. Reduction represents an unavoidable transient operation that if performed poorly can have a severe impact on the performance and lifetime of the LTS catalyst.

### Reduction

As with the majority of ammonia plant catalysts, the LTS catalyst is delivered and installed in its oxidic state and needs to be reduced before being placed into service. This reduction is achieved by passing hydrogen through the catalyst suitably diluted in an inert carrier gas. The hydrogen reduces the copper oxide leaving behind metallic copper crystallites. The amount of hydrogen controls the amount of exothermic reduction that occurs and hence the catalyst temperature, which has an impact upon the size of the copper crystallites and the achieved activity. Contaminants in the gas such as water and oxygen can have a deleterious impact on the formation of the copper crystallites and can result in a lower activity from the reduced catalyst.

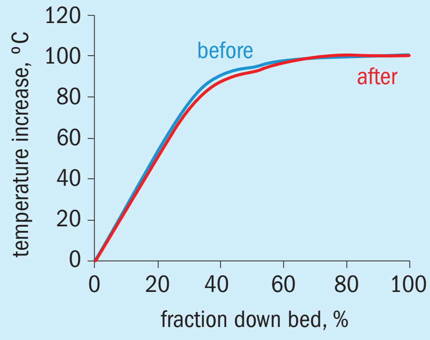
The inert carrier gas is typically nitrogen or natural gas and can be supplied as a once through stream or it can be recirculated using a recycle compressor. When nitrogen is used as the carrier gas, the recirculating system is normally used to avoid the excessive nitrogen requirements of a once through system.

When a recirculating system is used there needs to be a continuous purge from the system to prevent the level of contaminants from building up within the system. The oxidic LTS catalyst contains some complex copper-zinc basic carbonates and these decompose during reduction and release carbon dioxide. The amount of carbon dioxide in the recirculating carrier gas is one of the key parameters that determine the level of purging from the recycle loop.

There is a potential for the carbon dioxide in the recirculating gas to react with these carbonates and damage the microstructure of the catalyst.

The damage occurs primarily in the support phase of the catalyst, resulting in a weakening of the catalyst pellets. This is often observed as a higher than expected LTS pressure drop as soon as the plant is started up, which then increases rapidly during ongoing operation. Therefore, limits on the carbon dioxide partial pressure have been applied during some LTS catalyst reductions, with a figure of circa 1 bara being typical.

**Fig 6: Exotherm before and after wetting**



By optimising the catalyst formulation, an LTS catalyst can be developed where the catalytic species is supported on a backbone engineered to stabilise the active catalytic sites. By making a rugged stable support phase, the catalyst is less sensitive to the level of carbon dioxide in the reduction gas.

This has the benefit of reducing the cost of nitrogen or natural gas used during the LTS catalysts reduction, however, the main benefit is that it provides a larger operational envelope for catalyst reduction without risk of achieving a low catalyst activity. During LTS reduction, monitoring of the gas composition is often undertaken with temporary instrumentation and manual control of the purge flow. Therefore, a wider operating envelope within the period of less than ideal control is especially useful.

To illustrate this, a plant recently reduced a charge of $\text{KATALCO}_{\text{JM}}$ 83-3 Using a recycle system where hydrogen was added to circulating nitrogen. The hydrogen was sourced from the upstream plant with only the steam reformer and high temperature shift reactor in operation.

Therefore, the hydrogen contained more than 15% carbon dioxide as well as some carbon monoxide and methane.

During reduction the carbon dioxide content of the recirculating gas reached a very high level because of the concentrating effect of the impurities in the hydrogen supply and with constraints on the purge valve it was not possible to maintain this below the Johnson Matthey guideline of 20 mol-%. The carbon dioxide content peaked at 26.4 mol-% at an operating pressure of 15 barg giving a carbon dioxide partial pressure of 4.2 bara.

At the completion of reduction and start-up of the plant, the LTS catalyst was observed to have a pressure drop in line with expectation showing that there was no detrimental weakening of the catalyst despite the high carbon dioxide partial pressure. Ongoing operation over the following years has confirmed that the pressure drop remains in line with expectations.

It should also be noted that methanol synthesis catalyst is often reduced with such high levels of carbon dioxide present and methanol catalyst has a very similar composition and structure to LTS catalyst.

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## Topsoe experiences

In the following cases, Topsoe shares two experiences from the industry demonstrating that catalyst or equipment failure in a plant can result in severe implications. The examples are from shift operation, a very important process step in both hydrogen and ammonia plants. It is obvious that choosing the right catalyst for these applications is decisive when it comes to avoiding costly and potentially catastrophic catalyst failures.

### Securing low and stable MTS pressure drop

Topsoe has extensive industrial operating experience for MTS catalyst. The following case story from a European hydrogen plant illustrates the serious consequences that a plant suffers in case the MTS catalyst does not perform satisfactorily. Rapid pressure drop build-up in the MTS reactor does in many cases lead to unplanned shutdowns, incurring large costs due to downtime and lost production. Often unloading and recharging of the MTS catalyst is necessary in order to rectify the problem. In this case, installation of Topsoe MTS catalyst was the solution to the repeated problems experienced in the plant.

In 2007, this European customer installed a competitor MTS catalyst charge (A) in one of their two hydrogen plants. Due to problems with a high pressure drop, the charge was unloaded and replaced in 2009, after about 700 days in service. The charge was replaced with a new charge (B) from the same catalyst vendor. However, as Fig. 7 shows, a dramatic increase in pressure drop occurred for this second charge after about 400 days in service. Again it was necessary to unload and replace the catalyst charge. The customer decided to install a new charge (C) from the same competitor, but in 2012 after 500 days they were forced to replace it yet again due to another dramatic increase in pressure drop.

In April 2012, the customer installed a charge of Topsoe's LK-813/LK-817 catalysts (D). Since start of run, they were very pleased with the performance, with consistent low pressure drop and stable operation. As can be seen from Fig. 6, the performance of Topsoe's LK-813/LK-817 catalysts (D) is still superior compared to all three competitor charges, providing peace in mind and assuring safety during the expected lifetime. It has now been in service for over 1,000 days and is even expected to run for a few more years.

The experience from this hydrogen plant is evidence of how pressure drop problems can be managed by installing Topsoe MTS catalyst. In this case, it has brought great value to the customer through stable MTS service and low operational costs from running with consistently low pressure drop. Moreover, they have saved costs by avoiding a new catalyst purchase together with loading and reduction activities.

### LTS catalyst failure recovery

Topsoe is a world leader in LTS catalysis with a long and established record of high and outstanding performance, with more than 200 Topsoe LTS charges in operation globally. The first Topsoe LTS charge was installed in the 1960s, and the company has since accumulated a total of 4,500 years of operational experience in LTS vessels.

The focus for Topsoe's research efforts within LTS conversion is to provide state-of-the-art products that deliver the most cost-effective ammonia and hydrogen production in the industry. The performance of the LTS catalyst has a significant impact on overall plant efficiency, making it one of the most important catalysts in ammonia and hydrogen plants. Optimal performance of high-quality Topsoe LTS catalysts leads to maximum production of ammonia and hydrogen at no additional operating costs. The catalyst payback period is essentially insignificant considering the substantial increase in profits gained by plant owners who partner with Topsoe for their LTS needs.

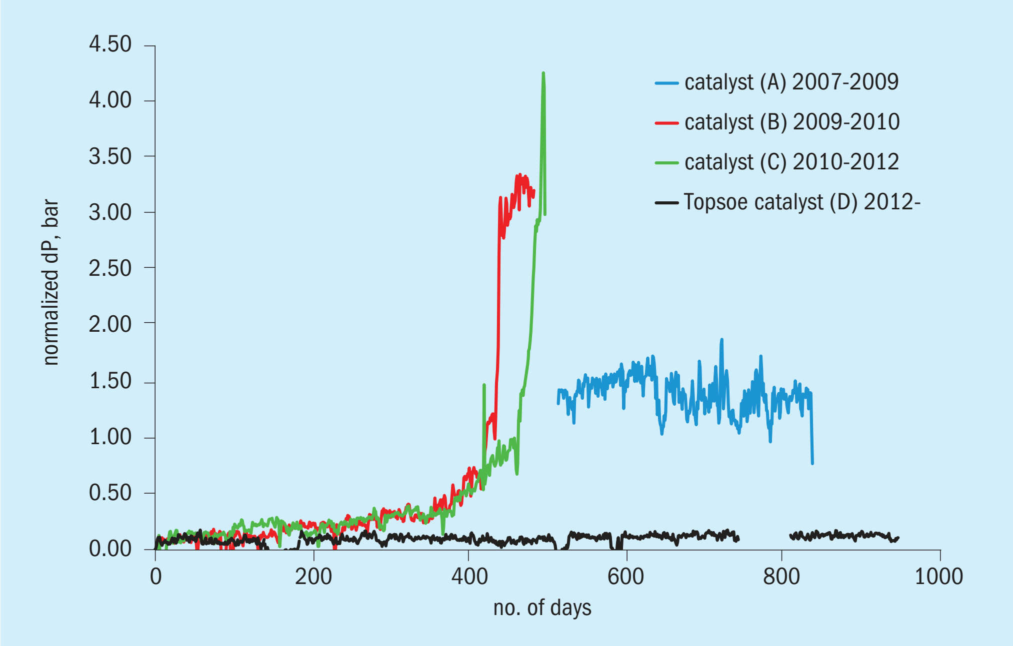
The following case story illustrates how quickly changing temperatures in a LTS reactor can affect an ammonia plant and the possible consequences it can have. In this case, an ammonia plant experienced a dropping LTS converter inlet temperature. When the inlet temperature passed the dew point it was decided to shutdown the plant and it was subsequently found that water could be drained from the bottom of the LTS vessel. This was a clear indication that the catalyst bed might be soaked in water, which poses a great risk of catalyst disintegration and as a consequence result in subsequent pressure drop build-up. It was hence critical to do a fast and focused effort on saving the LTS charge, in order to avoid a longer and more costly plant shutdown.

Topsoe's Technical Services was contacted and recommended draining the converter completely and afterwards applying a special drying procedure to avoid potential damage to the catalyst if water rapidly converts to steam in the catalyst.

After draining the converter and applying the Topsoe recommended drying procedure, operators at the plant examined the upstream BFW heat exchanger and discovered a leak. They repaired the leak and restarted the plant. The LTS catalyst charge continued normal operation with no signs of increased pressure drop, which could have been the result if the charge had been damaged. The catalyst was replaced about 3 years later, after a total operation period of 5½ years.

This example demonstrates how Topsoe Technical Services can save a catalyst charge, avoid damages, and enable a plant to restart as if nothing happened.

Fig 7: **Plant pressure drop before and after catalyst changes**



## Clariant experiences

Clariant describes a case in which the desulphuriser catalyst bed in a large capacity ammonia plant, not supplied from Clariant, became dislodged from its original position and catalyst particles were transported to the reformer causing high pressure drop in the reformer. Apart from the unplanned shutdown (and resulting costs), the customer suffered on extended shutdown. The reason cited was that due to haste during shutdown, the customer forgot to maintain the design layering recommended by the plant designer. The wire mesh that separates the catalyst and bottom inerts and is supposed to overlap the inerts and extend to the circumference was not maintained, making it easy for catalyst to slip thorough the inerts and find a way to block the pipe line.

Cleaning the entire transfer line was not easy. The main cause that resulted in this problem was the following:

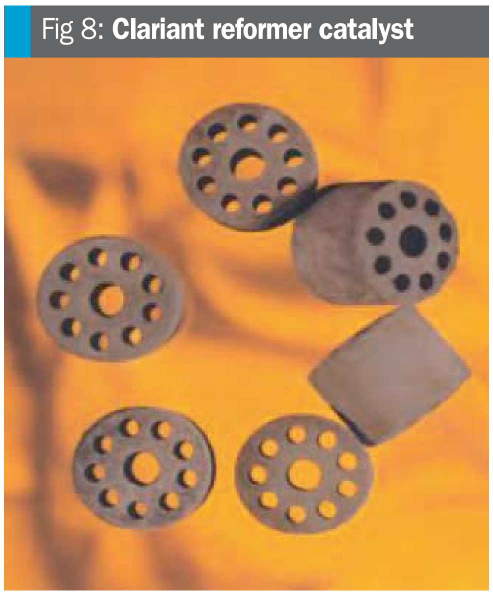
- original reactor layering was not maintained;
- pressure fluctuation while taking the reactor on line was abrupt.

The sudden pressurisation along with gaps in the bottom mesh caused the light zinc oxide particles to travel from the desulphurisation vessel to the reformer top causing high pressure drop and high tube wall temperatures on account of the masked nickel sites.

The tubular reformer is considered the heart of syngas operations. Catalyst is filled in tubes and fired externally. The catalyst loading of the reformer is very important as is the catalyst reduction and continuous monitoring. Performance to a great extent also depends on the efficiency of the purification catalyst. Poor loading can cause high pressure drop or channelling which may require a premature shutdown resulting in huge losses. Both start-up and shutdown procedures place extreme pressure on the catalyst. An optimised catalyst carrier and shape is therefore very important in achieving lower methane slip and longer activity without any increase in pressure drop. Figure 8 shows the physical shape of reformer catalyst where uniform radial crush strength is maintained by the orientation of the holes.

The secondary reformer (or auto thermal reformer, ATR) is one of the toughest applications for ammonia plant catalysts in terms of heat stress and physical integrity. Clariant and other catalyst suppliers offer optimised shapes such as Gatling gun for the top and bottom layering to prevent catalyst movement and alumina evaporation.

Fig 8: **Clariant reformer catalyst**



For each catalyst application an operating window is defined based on pressure, temperature and space velocity range. For a few sensitive catalysts (pre-reformer and LTS especially) some feed purity in terms of poisons is also specified. In certain applications, a minimum operating temperature is also influenced by other factors (process steam condensation/ dew point consideration in a low temperature shift converter especially during start-of-run (SOR) of fresh catalyst). Minimum operating temperature is usually selected as 25-30°C above the dew point of steam to prevent capillary condensation. Another negative aspect of condensation is that the poisons accumulated in the top layer of inactive catalyst will be transported to the good catalyst in the bottom further causing further poisoning in the lower section, resulting in shorter catalyst life. Even trace levels of chloride can rapidly increase the copper crystallites and reduce the activity almost irreversibly. Modern analysis techniques of spent catalyst can easily point out the presence of poisons in the feed. Every extra 0.1% extra CO slip from the LTS can reduce ammonia production by 7-17 t/d in a typical 1,000 t/d ammonia plant (a loss of approx. $1-2 million per year). Needless to say the loss will be more for a 3,000 t/d state of the art ammonia plant.

The typical LTS operating window is shown below:

| | |
|---|---|
| Temperature: | 195-230°C |
| Pressure: | 280 psig |
| S/G ratio: | 0.39 |
| Space velocity: | 4,000 Nm$^3$/m$^3$,hr |

These figures change according to the reactor configuration, plant type (e.g. ammonia or hydrogen), S/G ratio etc. LTS is the most sensitive catalyst even in the case of catalyst reduction and start-up. A controlled reduction is absolutely necessary for longer life. Clariant has seen several accidents where an uncontrolled reduction has caused failure and forced plants to take premature shutdown. Hence Clariant insists on being present to control the exotherm during reduction. Similarly for methanol synthesis catalyst which has very similar catalyst chemistry.

Operating catalyst at temperatures higher than required will lead to recrystallisation or thermal sintering resulting in irreversible loss of activity. The presence of certain compounds in the feed reduces the melting point of the active metal and speeds up crystallite growth (e.g. the presence of chloride in the feed to LTS catalyst). In addition, different active phases of the main ingredient can change the conversion efficiency of the catalyst (the iron carbide phase is active for the Fischer Tropsch polymerisation reaction and not in the desired CO conversion route in the case of a non-promoted high temperature shift catalyst (iron chrome). The overreduction of HDS catalyst to elemental metal when it comes into contact with hydrogen or reducing gas is another example of catalyst promoting undesired reactions caused by a mistake by a plant operator.

Even though catalysts have improved greatly in terms of physical integrity and catalytic properties, certain guidelines need to be followed during loading, reduction/ start-up and operation based on chemistry and poisoning or deactivation mechanism. It is also very important that plant operators are trained continuously in order to achieve trouble-free plant operation. ■

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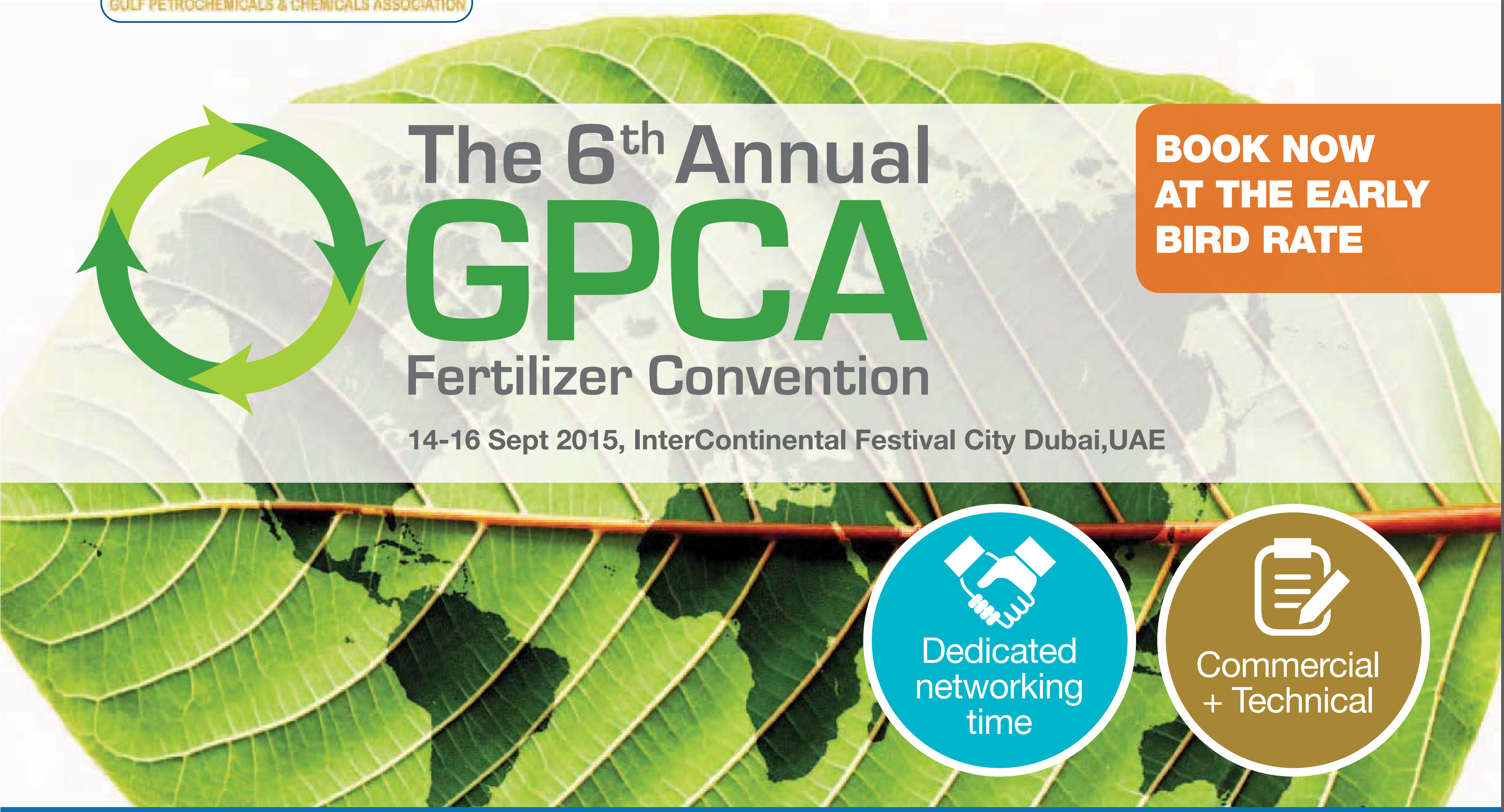

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