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Number 338
November | December 2015

# nitrogen+syngas

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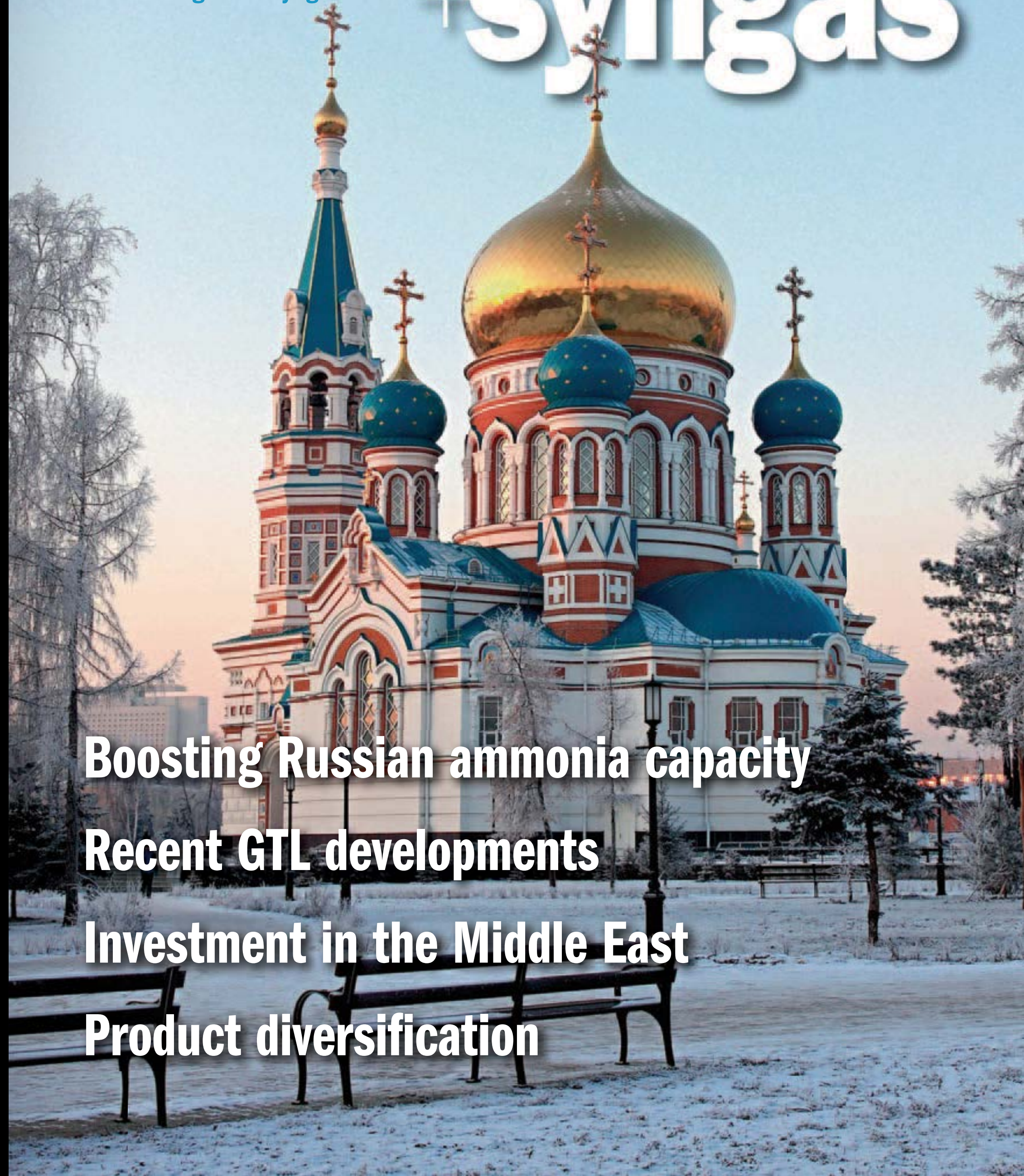

## Boosting Russian ammonia capacity
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## Investment in the Middle East
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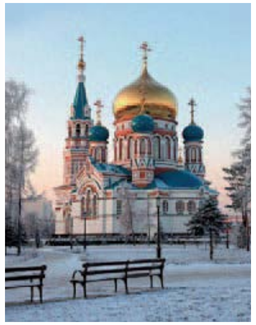

**Cover:** *Uspenskiy cathedral, Omsk, Russia. yykkaa/shutterstock.com*

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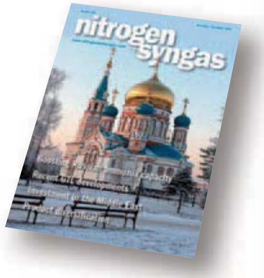
# Diesel – is urea the answer?




Living in London as I do, I'm well aware that diesel vehicles are not the 'green alternative' that they were sold as during the 1990s. Europe has enthusiastically embraced diesel vehicles – they now make up one third of all road vehicles across the continent and almost 60% of new vehicle registrations. It has caused major issues for Europe's refiners, configured to produce gasoline, who have had to export gasoline to North America and buy diesel from Russia. But while diesel vehicles had better fuel economy than gasoline cars – originally their great selling point – they are not as clean as they pretend to be. European city dwellers are very familiar with the soot that builds up near major roads – particulate matter including the lung-clogging PM10s and PM2.5s; particulate matter smaller than 10 and 2.5 micrometres in diameter respectively. And London has been fined by the European Commission for breaching roadside levels of nitrogen oxides – NOx – another major by-product of diesel's higher combustion temperatures. But how could so much NOx be being emitted, when EU emission limits for modern diesel cars were so low? There turned out to be a simple answer – the car manufacturers were cheating the emissions tests.

> **This trade-off between NOx emission and performance is inherent to diesel engines.**

In September, Volkswagen were discovered to have manipulated US emissions tests by getting the engine control unit in the car to run at its lowest emission rate only when it detected the car was being tested. At other times the engine was run at 'normal' parameters to avoid reducing the car's performance and fuel economy. This trade-off between NOx emission and performance is inherent to diesel engines, and soon other manufacturers were being accused, especially in Europe, of meeting only the laboratory tests that the EU mandates, while emissions could be up to 20 times higher during 'real world' driving conditions. Diesel passenger cars make up only a relatively small proportion of the US car market, but in Europe the scandal could have far reaching effects. The London city authorities have already appealed against the EC's fine, arguing that they were misled by car manufacturers.

So what is the solution? As nitric acid producers will be familiar, the main alternative to primary emissions reduction at the site of production is an end of pipe scrubbing system, using a solution of urea in water to release ammonia over a catalyst and selectively catalytically reduce NOx. This SCR technology is already mandatory on heavy duty vehicles, and the widely available urea solution is known as AdBlue in Europe and DEF (diesel exhaust fluid) in North America. Some diesel passenger car manufacturers such as BMW and some Mercedes-Benz vehicles use the same technology, but the urea solutions tank does add a small amount of cost and weight to the car, reducing performance slightly, and of course it must be regularly topped up, adding a level of inconvenience for drivers – larger tanks add more weight and cost, but smaller tanks must be topped up more frequently and add more inconvenience. Nevertheless, it is a reasonably practical refit to existing vehicles, and Volkswagen has already indicated that this may be its chosen solution to the emissions problem.

The diesel scandal may thus inadvertently end up being a major boost to European urea producers. Urea solutions use in Europe's heavy vehicles already represents over 2 billion litres, and with passenger cars also switching to the technology, Integer Research projects 6 billion litres of consumption by 2025, representing 600,000 t/a of urea demand. ■

*Richard Hands, Editor*





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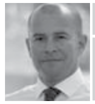
# Price trends



## MARKET INSIGHT

**Oliver Hatfield**, Director of Fertilizers & Chemicals, Integer Research, assesses price trends and the market outlook for nitrogen.

### NITROGEN

It's all about energy and currencies. Inevitably with a substantial supply overhang weighing down on nitrogen prices, all attention focuses on the position of marginal or swing producers and their production costs. In the last few weeks, currency and energy market fluctuations have led to further reductions in the urea market floor price. Between the beginning of September and the middle of October 2015, the price of prilled urea f.o.b. Black Sea had dropped from around $270 per tonne to $250 per tonne. Indeed, offers received for the latest MMTC Indian tender pointed to netback prices in China as low as $240 per tonne f.o.b. These are the lowest prices seen in the urea market since the credit crunch-related commodity price collapse at the end of 2008.

The decline has certainly unsettled parts of the market. The Chinese Nitrogen Producers Association (CNFIA) said that there would be consequences for any Chinese producer supporting traders selling product at the Indian tender price level. This would be considered to be selling below production cost. The CNFIA is not known to have any official or legal powers to penalise domestic urea producers, but previous pronouncements under similar market conditions have had a tangible effect, shoring up Chinese supply, at least temporarily.

The cause of the drop in prices is obviously abundant supply, but the ability of Chinese producers to offer volumes at lower prices is a logical consequence of what has happened to global currency exchange rates. The Chinese government's decision to devalue the Renminbi against the US dollar was intended to achieve exactly what we are seeing in the urea market and other export industries. Against a backdrop of static domestic demand and a limp economy, China wants to boost the competitiveness of Chinese exporters. So it's no surprise to see increased nitrogen export competitiveness and increased volume offered at lower prices.

Turning to energy markets, there's been little to offer support to nitrogen. Oil markets have remained oversupplied and prices relatively depressed since the oil price correction that caught many by surprise around a year ago. WTI crude oil is currently trading at below $50 per barrel, approximating to a gas price of around $8.00/MMBtu on an energy equivalent basis, which is only just above the level recorded briefly at the end of 2008 when the credit crunch shocked the market. The prices of gas in Europe and coal in China, the two key metrics influencing the production economics of swing nitrogen production clusters in those locations, are also at recent record low levels, flattening the global nitrogen cost curve and shifting the industry floor price down. In mid-October northwest European spot gas prices were trading at around $6.00/MMBtu, which is around half the level they were trading at just 18 months ago. In China the price of anthracite coal, the main feedstock used by a number of key urea exporting companies, has dropped below the equivalent of $5.00/MMBtu. Natural gas prices have also fallen in key producing locations like India and Ukraine, and shale gas continues to keep US spot gas prices below $3.00/MMBtu.

With a much flatter industry cost curve we need to be mindful not to read too much into the prevailing nitrogen market price weakness. We need also to remember that what we are seeing today is a cyclical price downturn in energy and nitrogen commodity markets, which naturally follows after the cyclical upturn we saw in the mid-2000s. Commodity clichés like 'the cure for high prices is high prices' are as relevant now as they were in many previous cycles.

A flatter industry cost curve has other implications for producer profitability and the influences of profits, which will be important to keep an eye on looking forward. When energy prices were at recent cyclical peaks, and the industry had little spare capacity, everyone made money, including the high cost, but profits for producers with low and fixed energy costs reached record levels. Those producers tend to be export located close to pockets of stranded energy and in that climate investment in expanding capacity looked attractive. With a lot of spare capacity today, and downward pressure on nitrogen prices, overall profits decline.

What's also interesting though is that with weaker energy prices, the profitability gap between the highest and lowest cost producers is much smaller. This tends to provide a significant disincentive to build new capacity. This means that over the next few years we would expect to see interest in building greenfield plants diminishing. After a while, capacity will grow more slowly than demand, utilisation rates will start to creep up, prices and profits will rise.… And in the words of the recently deceased Yogi Berra 'it's déjà vu all over again'. ■

**Table 1: Price indications**

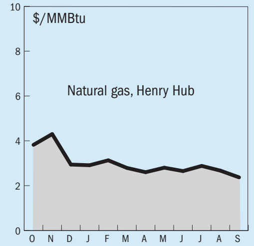
| Cash equivalent | mid-Sept | mid-July | mid-May | mid-Mar |
|---|---|---|---|---|
| **Ammonia ($/t)** | | | | |
| f.o.b. Caribbean | 405 | 420 | 425 | 435 |
| f.o.b. Arab Gulf | 420-450 | 380-400 | 350-405 | 400-430 |
| c.fr N.W. Europe | 474 | 455-480 | 460-480 | 473-510 |
| c.fr India | 463 | 420-455 | 410-450 | 490-500 |
| **Urea ($/t)** | | | | |
| f.o.b. bulk Black Sea | 255 | 262-273 | 275-283 | 270-280 |
| f.o.b. bulk Arab Gulf* | 266 | 268-278 | 308-335 | 270-275 |
| f.o.b. bulk Caribbean (granular) | 264 | 280 | 295-305 | 290-300 |
| f.o.b. bagged China | 263 | 282-287 | 293-308 | 275-283 |
| **DAP ($/t)** | | | | |
| f.o.b. bulk US Gulf | 458 | 470 | 468-472 | 485 |
| **UAN (€/tonne)** | | | | |
| f.o.t. ex-tank Rouen, 30%N | 186 | 195-197 | 185-190 | 231-235 |

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

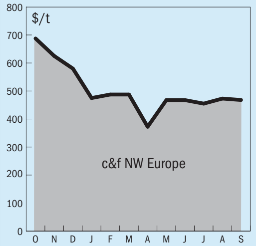


## END OF MONTH SPOT PRICES

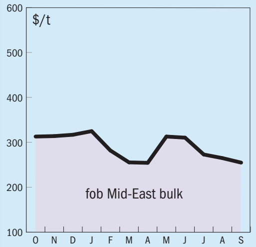
### natural gas



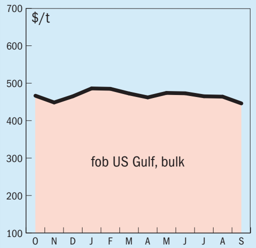

### ammonia




### urea




### diammonium phosphate




## MARKET INSIGHT

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

### METHANOL

The US September contract natural gas reference price was settled at $2.98/MMBtu for Texas, and $3.10/MMBtu for Louisiana, up $0.04 from August. Overall methanol demand was flat; weather conditions remain mild with temperatures still above freezing in the Northwest US, which translates to modest consumption of windshield wash and 'down hole' demand. Acetic acid, availability remains very good in the Americas, although one US production unit remains offline. Production across the Americas is also flat, although the Celanese Mitsui JV unit in Clear Lake, TX has now begun operations. IHS estimates the overall industry operating rate at 87%. In South America, market sources indicate that Venezuelan operations were disrupted near the end of September, but the units restarted at the end of October. Methanex's Chilean unit is operating at an estimated 30% after having been shutdown sometime in May due to lack of gas. Recent gas production increases lead to the Chilean government supplying Methanex with gas once again since the 25th of September which has allowed the company to restart one of the two remaining units in Punta Arenas. Supply has been assured to at least April of 2016 with the petroleum company optimistic that their finds will allow supply to continue for the next two decades. In Trinidad operations are estimated to be around 84% on average though another increase in natural gas curtailment (estimated to be around 30%) is believed to be looming in the near future. In company news, Syngas Energy Holdings announced plans to build a 500,000 t/a methanol unit in Louisiana, with construction expected to begin in the second quarter of 2016 and a targeted start-up in 2018.

The European market continues to be slow. Liquidity is low and reduced Rhine levels have discouraged consumers from purchasing barge material on an f.o.b. Rotterdam basis, as short-loading barges would increase the freight cost on a unit basis. EMethanex in Egypt is down due to restrictions in gas supply. Operating rates at a facility in the Black Sea are understood to be restricted due to limited gas availability. Market sentiment is mixed, with some participants expecting prices to rise in China and support European values. IHS forecasts a mild increase in pricing between October and November, on the back of a gentle recovery in Chinese demand. However, buyers are not purchasing more than they need for short-term operations. In addition, most vendors are reluctant to sell at current levels in a contango market structure. There has been interest in November material, although this is also fairly limited. IHS Energy expects that the crude oil price will reach a low in 1Q 2016, after which point it should recover gently, potentially leading to higher operating rates at Chinese MTO units. A stronger sentiment in China is something Europe will be looking for to boost market confidence. The outlook for Europe is unchanged, with supply healthy and demand stable, albeit at low levels.

In India, inventories at coastal ports are high and the market is oversupplied. Demand has weakened slightly ahead of the upcoming Diwali festival and there is a surplus of methanol, putting pressure on prices. Iranian producers continue to offer cargoes of methanol to Indian buyers but there were few bids if any for such material.

Asian market sentiment is relatively stable. In China, sustained weak buying momentum kept the market under downward pressure with a consistent decrease in the domestic price, driven by the weak futures market and flat demand. Overall buying enthusiasm from end-users is currently lacklustre since the downstream plants have no urgent spot need, having intensively purchased raw materials right after the October holiday. Prices on a dollar basis, however, are relatively stable. The current buying idea was around $235 per metric ton, and the selling idea is about $240 per metric ton. The availability of import material is not very high due to tight supply especially in Southeast Asia.

The overall operating rate remains at 55% of nameplate capacity and 72% of effective capacity. Coastal inventory is stable to slowly declining. Demand into key derivatives is generally stable; MTO is stable-to-strong with an average operating rate of about 70%. ■



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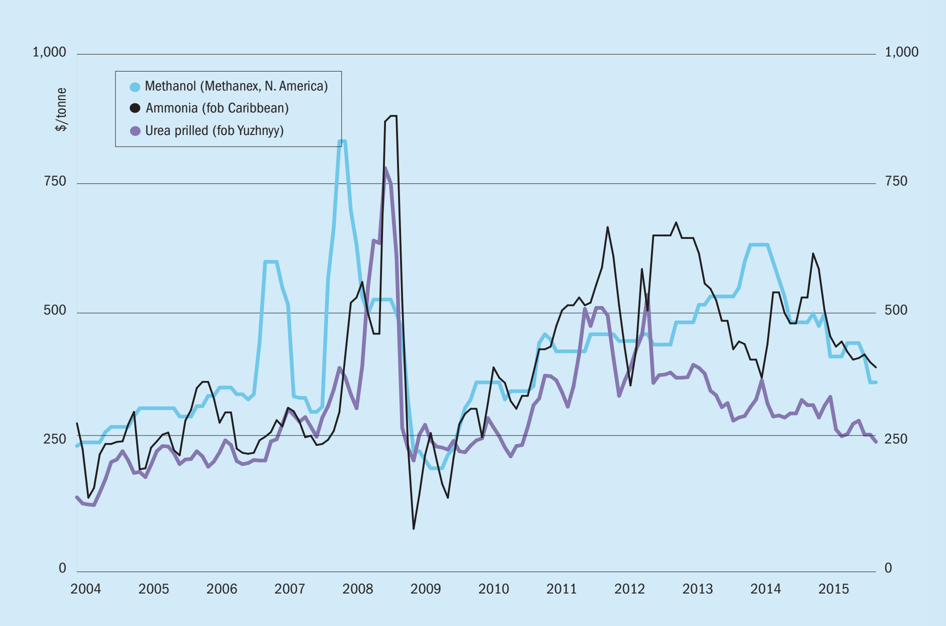
# Market outlook

**Historical price trends** $/tonne




*Source: BCInsight*

## AMMONIA

- Ammonia prices were once again impacted by sluggish demand in the first half of October, when prices were assessed at US$390-400/tonne FOB Black Sea.
- Although the world nitrogen market remains oversupplied, ammonia availability from key export regions has been tighter compared to other nitrogen products such as urea.
- Several plants in North Africa and the Black Sea were down in September due to maintenance intervals and unplanned outages, but this failed to stimulate any upward correction in ammonia prices
- Supply from Russian plants was fully committed in October and as a result Ukrainian producers were expected to step in and resume ammonia production now that their gas supply issues have been resolved.
- Refill demand from the US is likely to provide the next source of ammonia demand in November, and this is expected to improve market sentiment for the rest of 2015.

## UREA

- Urea prices fell to as low as $250/tonne FOB Black Sea in late October in the face of continued oversupply and improved cost competitiveness from export regions such as China and Russia.
- Demand was quiet in September and October, with the exception of two Indian tenders from MMTC, which were issued in late-September and mid-October.
- At press time there were expectations that urea prices could fall further in November amid weak market sentiment and a lack of sizeable demand outside of India.
- Despite this, it is expected that the warning from the Chinese nitrogen producer association, CNFIA, advising against lower price ideas will have some impact in keeping prices from falling much lower.

## METHANOL

- Trinidad and Tobago, with 6.7 million t/a of total methanol capacity, is expecting to have to institute further natural gas supply curtailments in the near future, with supply reduced by up to 30%.
- However, the start-up of the Celanese methanol plant at Clear Lake in Texas should keep US markets comfortable going into the winter demand season.
- Gas restrictions also continue to affect EMethanex in Egypt, but in Chile increasing gas availability has allowed one of Methanex's remaining plants at Punta Arenas to re-start, with supply available until at least April 2016.
- A recovery in oil prices in the start of 2016 may improve demand into Chinese methanol to olefin units, several more of which are coming on-stream over the next year, including some dependent on merchant production.
- Longer term the withdrawal of sanctions on Iran should boost supply out of the Gulf. ■





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# Nitrogen Industry News



**UNITED STATES**

## UN adopts development goals

IFA Chairman Abdulrahman Jawahery has congratulated world leaders for adopting the United Nations' Sustainable Development Goals (SDGs) at a meeting in New York. "The SDGs adopted today – following many years of productive and inclusive dialogue – set an important roadmap for the entire international community to pursue sustainable development," he said. "This represents an impressive achievement, and the onus is now on all of us to roll up our sleeves and implement these ambitious but feasible goals."

The SDGs come into effect from 2016 and run to 2030. IFA and its members have been actively engaging in the post-2015 debate, and applaud in particular the emphasis placed on improved productivity and improved access to inputs by smallholder farmers, for the promotion of agricultural research and extension services and support for investment in rural infrastructure, as well as the focus placed on the need for more sustainable agricultural production.

"Plant nutrients – of organic and mineral nature – contribute to many of the 17 SDGs, but of course mainly to Goal 2 on eradicating hunger and malnutrition," said IFA Director General Charlotte Hebebrand. "Balanced and correct fertilizer use plays an important role in sustainable agricultural intensification, which allows for greater productivity and a wiser use of limited natural resources, and also minimizes nutrient losses to the environment, including to the world's oceans, as highlighted in Goal 14."

The focus now switches to the Indicators, which are still under negotiation and overseen by the UN High Level Political Forum. IFA's commitment to the SDGs and post-2015 agenda continues, reinforced through the presence of a delegation to the SDG Summit and the UN Global Compact Private Sector Forum, comprising of Tip O'Neill, CEO of International Raw Materials Ltd and Svein Tore Holsether, CEO of Yara, as well as Barrie Bain, Senior UN Adviser, on behalf of the Secretariat.

**INDIA**

### Mitsubishi in sales joint venture

Mitsubishi Corporation says that it has entered into an agreement with the Indian Farmers Fertiliser Cooperative Ltd (Iffco) to establish a local enterprise for the sale and distribution of agrochemicals in India. The new company, Iffco-MC Crop Science Pvt Ltd (Iffco-MC), will be 51% owned by Iffco and 49% by Mitsubishi. Iffco has built up a respected national brand as India's largest producer and distributor of fertilizers, delivering fertilizers to farmers via their nationwide cooperative society network. According to Mitsubishi, Iffco-MC will be seeking to leverage the strength of the Iffco brand and its extensive sales network to supply a number of agrochemicals, mainly herbicides, insecticides and fungicides, to the Indian market, starting in October of this year.

India's agrochemicals market was valued at some $2 billion in 2014 and accounts for about 5% of the global total. As its population increases and as daily food consumption patterns evolve, this volume is expected to continue showing robust growth, and is projected to reach a value of approximately $3 billion in FY 2017.

### Gas prices fall for fertilizer producers

In the wake of falling global gas prices, the Indian government has decided to decrease the gas price paid by domestic fertilizer producers by 18%, to $3.82/MMBtu. The change, effective from October 1st, will be fixed until the end of March 2016. Indian fertilizer producers have – unsurprisingly – been extremely appreciative of the move, and fertilizer shares jumped on stock markets. Oil and gas producers, conversely, have argued that setting sales prices too low deters exploration and investment in new gas supply development – something India has a chronic shortage of.

### Environmental clearance deferred on Shyam

India's Environment and Forestry Ministry's expert appraisal committee (EAC) has deferred a decision to grant environment clearance to the Krishak Bharati Cooperative (Kribhco) Shyam Fertilizers expansion in Uttar Predesh state. The proposal is for a new 2,200 t/d ammonia plant and 3,850 t/d urea plant at the existing Kribhco Shyam Fertilizers Ltd Shajahanpur site, where the company already has 1,350 t/d of ammonia and 2,250 t/d of urea capacity. The site had been cleared for a debottlenecking to 1,950 t/d of ammonia and 3,130 t/d of urea capacity in 2008, but this was not implemented. The EAC said that it wanted to visit the site to assess the environment compliance of the existing unit and any related issues to be addressed.

However, the ministry EAC has environmentally cleared an $840 million fertilizer plant project in Ramagundam, Telangana state, being developed by a joint venture between National Fertilizers Ltd (NFL), Engineers India Ltd (EIL) and the Fertilizer Corporation of India Ltd (FCIL). The new joint venture company, Ramagundam Fertilizers and Chemicals Ltd, is for a 1.1 million t/a ammonia-urea project, at an existing brownfield site. It is expected that the local state government will also take a stake in the JV. The existing Ramagundam fertilizer plant was a coal-based ammonia-urea unit which has been closed for many years.

### Bids invited to revive Sindri urea plant

The Indian government has issued a global tender for investors to revive the closed Fertilizer Corporation of India (FCIL) urea plant at Sindri in Jharkhand state. Cost estimates run at up to $1 billion for the project, which aims to find an investor to design, finance, construct, operate and maintain a gas-based ammonia-urea plant at the site for 33 years. Projected urea capacity is 1.27 million t/a. The project has to be completed within three years. Natural gas for the project is proposed to be available via a forthcoming expansion of the Jagdishpur-Phulpur-Haldia (JPH) pipeline, to be constructed by GAIL India.

**AUSTRALIA**

### Downer sues Tecnicas Reunidas over Burrup plant

Australian engineering firm Downer EDI is pursuing $60 million in claims from Spain's Tecnicas Reunidas for work on Yara and Orica's Burrup Nitrates ammonium nitrate plant in Western Australia, after terminating its construction contract with the Spanish group. Downer said that the decision was not taken lightly, but that it considered it had "no alternative given Tecnicas Reunidas' conduct" following "a failure by Tecnicas Reunidas to remedy a substantial breach of the contract."

Tecnicas Reunidas is the lead contractor overseeing the construction of a $600 million (A$840 million) ammonium nitrate plant on the Burrup Peninsula near Karratha. Burrup Nitrates is 45% owned by Orica, 45% by Yara International, and 10% US oil and gas exploration group Apache. Downer was awarded a $72 million structural, mechanical and electrical contract in March last year to build the plant and install pre-fabricated modules supplied by Tecnicas Reunidas, but the modules supplied by the Spanish group are alleged to have been poor quality, with parts not fitting together. Downer has been paid about $89 million by Tecnicas Reunidas for its work on the plant and some additional claims, but plans to refer an extra $60 million of claims to arbitration. The arbitration process is expected to take about 18 months.

### Leigh Creek to develop UCG, looking at AN production

Leigh Creek Energy is aiming to build a $1 billion underground coal gasification (UCG) project to supply gas to Australia's eastern states, via a large coal deposit which Alinta Energy is about to abandon in South Australia. Alinta Energy has mined coal from the deposit 550km north of Adelaide, which is owned by the South Australian state government, for 70 years, feeding two coal-fired power stations at Port Augusta, but the company says that it will close the coal mines this year and shutter the power stations by March 2016 because of weak wholesale power prices. However, the South Australian government has a legislative framework in place for unconventional gas, and Leigh Creek Energy now holds licenses for the coal deposit, where it aims to use in-situ gasification to produce syngas within three years. The development of the site has been accelerate, according to the company, because of existing infrastructure which will be left behind by Alina, including an airport, rail link and electricity supply. Appraisal drilling will begin in November to more accurately quantify the coal and gas volumes.

Capital spending is earmarked to be A$500 million over the first three years, with three options under consideration for a pipeline to link up to the existing Moomba pipeline at the Cooper Basin in the north of South Australia, which is itself connected to the eastern states gas network. Leigh Creek also indicates that it plans to develop an ammonium nitrate plant to supply the fertiliser and industrial explosives industries, and that the entire project could be worth up to $1 billion.

**NETHERLANDS**

### Fire shuts OCI's Geleen facility

A fire that broke out at OCI's Geleen nitrogen facility on September 30th has prompted a stoppage of ammonia, CAN and UAN production. The fire broke out in an underground area of the plant during maintenance work at the site. There were no reported injuries, and both ammonia plants have since re-started, with the UAN and one of the melamine plants following soon after, but damage to the site has kept the calcium ammonium nitrate (CAN) plant closed during October and into November. The Geleen plant operates 1.1 million t/a of ammonia capacity, 250,000 t/a of UAN, 1.4 million t/a of CAN and 150,000 t/a of melamine.

**ZIMBABWE**

### Sable closes ammonia plant again

Sable Chemicals has been forced to close down its electrolysis-based ammonia plant at Kwekwe, Zimbabwe, due to power shortages. The 80MW plant had already been operating at 50% capacity after closing five of the 10 electrolysis units, which generate hydrogen for ammonia production, but state power supplier the Zambia Electricity Supply Association (Zesa) has further scaled back supplies of electricity. Low water levels at the Kariba dam, shared with neighbouring Zambia, and constraints on power import and generation have led to power cuts lasting up to 18 hours per day in Zimbabwe. Also at issue is the subsidised rate at which Sable buys power from the grid, reckoned by Zesa to be less than 50% of the going rate.

The ammonia is used for downstream ammonium nitrate production, and Sable can switch to imports of ammonia from South Africa, as it has done on occasions in the past, but the company says that it is still owed $200 million by the government and may not have the wherewithal to import large volumes until this is paid. As a consequence, Sable has cut its AN production forecast from 100,000 t/a this year to 70,000 t/a.

**OMAN**

### Eight firms pre-qualified for Salalah

A total of eight engineering firms have been pre-qualified by the Salalah Methanol Company to bid for construction of its new 1,000 t/d ammonia plant at the firm's site in the Salalah Free Zone in Oman. The state-run petrochemical company, jointly owned by the Oman Oil Company (90%) and locally-based Takamul Investment Co (10%), plans to use a hydrogen-rich purge gas feed from the adjacent 3,000 t/d methanol plant as feedstock. Costs for the project are estimated at $750 million.

The pre-qualified contractors include several South Korean companies, including Samsung Engineering, Daelim Industrial Company, Hanwa Engineering & Construction, and GS Engineering & Construction, as well as India's L&T Hydrocarbon Engineering, Taiwan's CTCI Corporation, SNC-Lavalin of France, and Spain's Tecnicas Reunidas. An invitation to bid for the EPC contract is due to be floated in 4Q 2015.

**MALAYSIA**

### Ammonium nitrate plant to close

The Chemical Company of Malaysia Bhd (CCM) says that it is shutting down its 240,000 t/a fertilizer grade ammonium nitrate plant at Shah Alam and laying off 232 staff due to "prolonged negative market conditions". The company said in a statement that demand for AN-based fertilisers has reduced over the last five years, and that the outlook is likely to see its major customers in oil palm cultivation continue switching to cheaper fertilisers such as urea and NPKs due to the downward trend in prices of crude palm oil. CCM said that, barring unforeseen circumstances, the closure of the plant will be completed by the end of June 2016.

**CHINA**

### Ammonia leak hospitalises 41

A major ammonia leak at Henan Zhonghong Coal Chemical Company in Henan province has hospitalised forty-one people according to local media reports, with five said to be in a "serious" condition and some reports of one death from ammonia inhalation. A reported 300kg of ammonia leaked from a ruptured pipe at the site, with 154 local residents initially admitted to hospital and 41 kept in for observation.



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The accident occurred in the early hours of the morning and left wildlife and domestic animals dead and a low-lying ammonia fog over the village near the plant.

## IRAN

### Iran sets gas price for Indian urea plant

Iran has offered natural gas to India at the rate of $2.95/MMBtu for a 1.3 million t/a ammonia-urea plant India wants to set up at Chabahar in the southeast of the country. The price is reportedly considerably higher than the $1.50/MMBtu that India is angling for, and discussions are said to be continuing. A previous attempt to set up an Iranian-Indian joint venture ammonia-urea plant at Kharg Island in the 1990s foundered over gas price discussions.

## SLOVAKIA

### Alfa Laval to supply ammonia WHB

Alfa Laval says that it has won an order to supply equipment items to the new Duslo AS ammonia plant being constructed at Sala. The order, worth $6.7 million, is for a waste heat boiler for the heat recovery system, and is scheduled for delivery in 2016. The 1,600 t/d ammonia plant is being constructed by Technip on a lump sum turnkey basis, with Haldor Topsoe licensing its technology for the unit. The plant is scheduled for completion in 2018.

## GERMANY

### BASF announces rationalisation of catalyst production

BASF says that it will consolidate its spent chemical catalysts refining and recycling operations to the company's Seneca, South Carolina, operating facility by the end of 2015. As a result, the company says that it will shut down the incineration and refining of used chemical catalysts at its operating site in Rome during 4Q 2015. The Rome site's operations will instead focus on process catalyst manufacturing, platinum group metals (PGM) salts and solutions production, and assay laboratory testing and analytics. BASF says that this consolidation will lead to a reduction in staffing at the Rome site.

"This operational consolidation will allow BASF to leverage our existing processing capacity and recycling expertise in Seneca, optimizing our overall production efficiencies for the refining and recycling of recovered platinum group metals in the face of an increasingly challenging global commodities market," said Deon Carter, Senior Vice President, Precious Metals Services with BASF. "The Seneca site already serves as BASF's global PGM recycling hub, where precious metals recovered from spent chemical catalysts and auto catalysts are refined for use in a new generation of catalysts that support clean air and improved production efficiency for a broad range of chemical and industrial applications."

To support this operational consolidation, BASF's site in Cinderford, UK, will now serve as a regional transfer centre for all European spent chemical catalyst recycling customers, providing centralised collection, documentation and transfer services. The site will also continue to serve as BASF's European recycling hub for scrapped auto catalysts, where PGMs are recovered and shipped to Seneca for further refining and use in next-generation emissions catalysts.

*Catalyst recycling at BASF's Cinderford site.*

## AZERBAIJAN

### Talks resume on urea plant financing

The State Oil Company of Azerbaijan (SOCAR) has resumed negotiations with South Korean investors, including the Export-Import Bank of Korea, about financing for the construction of an ammonia-urea plant at Sumgait on the Caspian Sea cost. SOCAR vice president Suleyman Gasimov said that the resumption of talks became possible after a review of the financial structure of the project due to the decline in world oil prices.

The project, for a 1,200 t/d ammonia and 2,000 t/d urea plant, began construction in February 2014, with Samsung Engineering as the turnkey EPC contractor, and technology licensed from Haldor Topsoe for the ammonia plant and Stamicarbon for the granulated urea plant. The initial cost estimate of the project was $650 million, of which $150 million has already been provided by the Korean Eximbank to Samsung for purchase of equipment items.

SOCAR expects to begin production in 2017, with output initially targeted at the domestic market in Azerbaijan, but also with the anticipation of exports to Turkey and other international markets in the longer term.

## TANZANIA

### Joint venture established for new fertilizer complex

The state-owned Tanzania Petroleum Development Corp. (TDPC) and a consortium led by the German company Ferrostaal has entered into a joint venture to realise a new world-scale fertilizer complex in Tanzania. The investment volume for the project will be more than $1 billion. The complex will be the largest German investment in Tanzania and the first fertilizer plant in the country. Located in the south of Tanzania, the ammonia-urea complex will be operational in 2020, according to Ferrostaal, producing 1.3 million t/a of urea.

Dr. James Mataragio, managing director of TDPC said: "For the economic development of Tanzania, especially for the agricultural sector, we expect a huge effect from the plant. It will increase the value creation in Tanzania significantly. Now, we are looking forward to taking the project to the next level." Together with its local partners Tanzania`s National Social Security Fund, the largest public investment fund in the country providing social security protection in Tanzania, and Minjingu Mines & Fertiliser Ltd, a major producer and distributer of fertilizer for East, Central and Southern Africa, the joint venture will now accelerate negotiations relating to the gas supply for the project.

"This agreement marks a major step forward to boost fertilizer production in Tanzania. The joint venture underscores our commitment to Tanzania to turn this important project into reality. Combining the competence of facilitating investments with the world`s leading technologies is our key to success", said Dr. Klaus Lesker, managing director of Ferrostaal Industrial Projects Gmbh.

Ferrostaal is partnering on the project with Haldor Topsoe A/S, which will license technology for the ammonia plant, and Pakistani fertilizer producer Fauji Fertilizer Company Ltd, which will be responsible for the offtake from the plant. ■





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# Syngas News

GERMANY

## Linde commissions new syngas research plant

The Linde Group has commissioned its new Linde Pilot Reformer research facility at Pullach near Munich, part of the company's largest site worldwide, at an event attended by customers, partners and employees. The company has invested approximately €5 million to expand Pullach's research and development capacity, including the new pilot reformer, which will be used to refine steam reforming technology for the production of synthesis gas.

"The official opening of the pilot reformer provides further proof of our customer-centric approach to development and sends a strong signal confirming Germany's role as an innovation hub," commented Dr Wolfgang Büchele-Londe's CEO.

"Linde intends to use this pilot facility to test and optimise all kinds of approaches to reforming. The insights we gain will help us further improve reforming processes and concepts for our customers," added Dr Christian Bruch, member of Linde's executive board responsible for technology and innovation as well as the Engineering Division.

Tests in the pilot reformer are currently focused on the 'dry reforming' process, developed by Linde in cooperation with partners BASF and hte (responsible for catalyst development), the Karlsruhe Institute of Technology/KIT (responsible for simulations) and DECHEMA (supplier of materials). The pilot project has also been awarded funding by the German Ministry for Economic Affairs and Energy (BMWi) of just under €1 million. The dry reforming process uses carbon dioxide as a feedstock to produce syngas, which Linde is significantly more energy efficient than conventional reforming or partial oxidation. If the dry reforming pilot proves successful, there are plans to commercialise the process when the funded project comes to an end in 2017, and build a reference plant for a Linde customer.

CHINA

### First reference for Clariant sour gas shift catalust

Clariant says that it has achieved successful start-up and operation of its presulphided *ShiftMax*® *820S* sour gas shift catalyst at a commercial facility – a methanol plant belonging to Shanghai Huayi Energy Chemical Co. Ltd. ShiftMax 820S SGS uses a proprietary pre-sulphiding process, with advantages for coal-to-chemical producers. It improves working conditions by avoiding the use of flammable and toxic species such as carbon disulphide or dimethyl sulphide during the commissioning phase., and reduces the risk of high It is also typically ready for start-up three times faster than conventional catalysts. The higher activity of 820S reduces syngas and energy requirements, allowing more efficient operation.

Another recent introduction is a new sour gas shift process, jointly developed by Clariant and Siemens. Through optimisation and simplification of total plant concepts, Clariant says that the new process reduces capital expenditure for the shift system by up to 20%, and optimises operating costs with up to 30% lower catalyst volume. The technique can handle different steam-to-gas ratios and high carbon monoxide content without adjustment of the feed gas, resulting in improved availability and reliability of the whole process.

Shanghai Huayi Energy Chemical Co. Ltd is one of the largest methanol producers in China, with an annual production capacity of 1.6 million t/a.

### Continuing growth for coal to olefins

Chinese consultancy firm AsiaChem says that it believes China's coal gasification capacity in 2020 will amount to 173 units larger than 3,000 t/d of coal. Although the fall in the international oil price to $50-60/bbl has prompted the Chinese Ministry of Environmental Protection to increase its scrutiny and tighten approval criteria for new coal chemical projects, the company says it believes that this will slow the pace of development, but not stop it. The large gasification plants span six main areas – coal to liquids (CTL), coal to methanol/olefins (CTO), coal to synthetic natural gas (SNG), coal to large scale ammonia, coal to ethylene glycol and coal to hydrogen, and a large number of coal chemical projects will finish construction and be commissioned in the period 2016-2020. AsiaChem puts the total syngas generation at 57 million Nm³/h, with coal to synthetic natural gas (SNG) accounting for the largest share for coal gasification market. Newly added coal to methanol projects are relatively fewer; most new coal to methanol units are integrated into downstream coal to olefins projects, which will account for 16% of the new gasifiers completed to 2020. Meanwhile, while the number of coal to ethylene glycol projects is relatively higher, the syngas requirement for any single project is small, and hence these represent only 6% of new gasification capacity.

AsiaChem also notes that, should the international oil price rebound to about $80/bbl, China will probably build considerably more coal chemical projects in addition to those which are counted in the totals above, and the coal gasification market will substantially increase, while if oil prices fall below $50/bbl, the enthusiasm for new coal gasification capacity will be greatly reduced.

### Synthesis Energy Systems highlights gasification progress

US-based Synthesis Energy Systems (SES) highlighted progress with a number of Chinese gasification projects during its recent half year results presentation. In December 2014 the company was awarded three project licenses and equipment orders related to its Tianwo-SES joint venture for the Aluminium Corporation of China. This involves the fast track construction of three industrial coal gasification systems to generate syngas for electricity production to replace expensive natural gas. The first two CHALCO industrial syngas projects are expected to operational by the end of 2015, with the third project to follow in 2016, and will expand the company's installed based in China from 5 to 12 SES gasification units. SES says that the process is allowing it to gain knowledge which will allow it to modularise its technology to be more efficient and competitive in order to expand into larger scopes of supply with turnkey capability. SES also says that China is no longer routinely granting permits for new coal-fired power plants, and that combined cycle gasification is not only more efficient than coal but also allows easier recovery of $CO_2$ for capture and storage.

Meanwhile, the company's ZZ joint venture gasification-based methanol plant, which has suffered with the lower methanol price environment, has been expanded to produce downstream acetic and propionic acid, improving profitability. The larger Yima methanol facility in Henan Province has achieved up to 80% production during summer 2015, and aims to reach 100% capacity by February 2016, according to SES.



EGYPT

### Massive gas find off Egypt

Italian energy group Eni says it has found one of the world's largest natural gas fields off the northern coast of Egypt. The company said the area was found 1.45 km down, and covers 100 km². Provisional estimates of gas in place are as much as 30 trillion cubic feet (tcf) of gas (850 bcm), or 5.5 billion barrels of oil equivalent (bboe), Eni said. The company says that the Zohr field "could become one of the world's largest natural gas finds" and help meet Egypt's gas needs for decades. Most of the gas is expected to be used domestically by Egypt, although there is the potential for export, via an existing LNG plant that Eni has not far from the field. The discovery follows other significant gas finds in the eastern Mediterranean in recent years, including by Egypt's neighbour Israel. It could also be a boost for Egypt's nitrogen and methanol industries, which have suffered from gas curtailments in recent years as production fails to keep up with surging domestic demand.

TRINIDAD & TOBAGO

### New gas expected by 2020

Trinidad, also suffering gas curtailments due to the run down of older fields, is placing its hopes on the new Loran/Manatee gas field, which sits on the maritime border between Trinidad and Venezuela. However, Thackwray Driver, CEO of Trinidad's Energy Chamber, told local media that he does not expect the first gas to come from the Loran/Manatee field before 2020, as there are still many commercial agreements which remain to be negotiated, including gas sales contracts and field development agreements. The purchase of BG – the discoverer of the field – by Shell also means that there may be a new entity entering into the discussions in 2016. BG has said that Venezuela has agreed to allow some of its share of the gas field's production to be processed in Trinidad and Tobago and exported as LNG via Trinidad's Atlantic LNG plant at Point Fortin.

Trinidad has faced output restrictions at the country's ammonia and methanol plants as well as lower LNG exports because of lower gas production, with domestic power production prioritised. Trinidad is producing about 400-600 million cubic feet less gas per day than it requires to run its gas export and petrochemical plants at capacity. Gas producers have blamed low fixed gas prices for the shortage, arguing that there is plenty of gas in place around the island, as the recent discovery proves, but that at current prices it is not economical to drill for it, and it will be interesting to see what price is negotiated for the new Loran/Manatee gas, at a time when Trinidadian producers face increasing competition from new US shale gas-based ammonia and methanol production.

UNITED STATES

### Ground broken on new methanol plant

Ground has been broken on a $1.85 billion methanol development in Louisiana funded by Chinese money. Shandong Yuhuang Chemical Co. will develop the 5,000 t/d methanol plant in Louisiana's St. James Parish, between New Orleans and Baton Rouge, with start-up expected in 2018. Amec Foster Wheeler has been awarded the

*Atlantic LNG – Trinidad's main gas export terminal.*



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engineering services, project management, procurement and early construction services contract, for an undisclosed sum, which will reportedly become a full EPC contract next year. The plant will use Air Liquide's Lurgi *MegaMethanol* technology.

Meanwhile, in Washington State, federal and state regulators are considering permit applications for the first of three proposed $1.8 billion methanol plants for the region. Chinese project developer Northwest Innovation reportedly wants to start construction on the first plant, at the port of Kalama, Washington, in 2Q 2016, aiming to produce methanol for export to China to feed new methanol to olefins (MTO) capacity. The US Army Corps of Engineers is considering a clean water permit for the plant, which would be constructed along the Columbia River, while the Department of Ecology will decide whether to issue a permit for the company to build a natural gas pipeline to supply the necessary feedstock to make methanol.

### Velocys settles IP dispute

Gas-to-liquids specialist Velocys has settled an intellectual property infringement case with use UK chemicals multinational Johnson Matthey. Velocys filed the lawsuit against Catacel, a supplier of catalysts to Compact GTL Limited's gas-to-liquids demonstration unit at its Petrobras' facility in Aracaju, Brazil, claiming infringement of several of the company's US patents. Catacel was acquired by Johnston Matthey in September 2014. Under the terms of the settlement, Johnson Matthey will pay Velocys an undisclosed amount in recognition of its intellectual property. Velocys had previously undertaken successful litigation against Compact GTL in the UK after Compact infringed Velocys's patent claims relating to Compact GTL's UK pilot plant activities.

## CANADA

### Atlantic Hydrogen files for bankruptcy

Clean energy start-up company Atlantic Hydrogen has filed for voluntary bankruptcy. The company had been developing a chemical process to dissociate methane into carbon and hydrogen to produce a zero-$CO_2$ source of hydrogen for industrial use. However, chairman Bill Stanley said that the 11-year-old company had been taking too long to reach commercialisation of the technology, and consequently had had difficulty attracting investment this year. Emera, which also owns Nova Scotia Power, had invested C$10 million in the firm, but wrote down C$8.8 million of its equity investment in early 2014, saying Atlantic Hydrogen's path to commercialisation was "a question mark". A demonstration plant for the *CarbonSaver* technology was due to be built at Emera's Bayside power plant in St. John, New Burnswick, but this was not completed due to "technology and funding challenges".

## CHILE

### Gas supply agreed for Methanex methanol plant

ENAP, Chile's state-run oil and gas company, has agreed to supply gas to Methanex's remaining methanol plants at Punta Arenas in southern Chile. ENAP says that, based on successful development of its Arenal block in the extreme south of the country, it has reached a natural gas supply agreement with Methanex to supply 400,000 $m^3/d$ from September 25th until "at least" April 2016. Methanex had developed Punta Arenas into a major methanol hub during the 1990s, but gas supply restrictions from its Argentinian partner over the past few years have forced it to relocate two of the units to Louisiana – one started up recently and the other is under reconstruction. This leaves only two methanol units at Punta Arenas, one of which has been idle and the other operating at reduced capacity.

ENAP says that successful exploration and production at the Arenal block could probably ensure supply for the region for the next two decades, and added that the deal with Methanex reaffirms its commitment to ensuring a sufficient supply of natural gas at affordable and sustainable rates, while at the same time increasing economic activity and contributing to the development of the region and living conditions of its people.

## AZERBAIJAN

### AzMeCo starts receiving Russian gas

Gas supplies from Russia's Gazprom Export to Azerbaijan's methanol AzMeCo methanol plant at Garadagh began in September. President of Azerbaijan's state energy giant SOCAR Rovnag Abdullayev said that AzMeCo will purchase up to 2 bcm per year of gas from Gazprom, ensuring that the plant can operate at 100% capacity. As reported last issue, AzMeCo is taking advantage of a clause in Gazprom's 2009 gas purchase arrangement with SOCAR because SOCAR itself was not able to guarantee a supply of gas in what AzMeCo regarded as a "timely manner".

## SUDAN

### Agreement signed for GTL plant

The Sudanese ministry of oil, via its state-owned Sudapet company, has signed a $70 million with Russian technology company Gazohim Techno to develop a gas to liquids project in the country. The proposed plant will convert 10 million cfd of gas from the Neem field in western Sudan to produce an estimated 100,000 t/a of synthetic fuel products. Sudapet will own 51% of the plant and the remaining 49% will be held by the Russian company. The project will be implemented within 18 months, according to Sudapet. Gazohim Techno licenses the small-scale modular GTL technology from Velocys Ltd, which is backed by UK-based Russian billionaire (and owner of Chelsea football club) Roman Abramovich.

## TURKMENISTAN

### GTL plant for Turkmenistan

A large plant for producing liquid fuel from natural gas via gas to liquids (GTL) technology will be constructed in Derweze district of Turkmenistan's Ahal province, according to the country's Ministry of Oil and Gas Industry and Mineral Resources. The new plant will process 3.8 bcm/year of natural gas and produce 1.7 million t/a of liquid fuel per year. EPC contracts for the plant have gone to a consortium led by South Korean firms Hyundai Engineering Co. Ltd. and LG International Corp., with a value put at $3.89 billion. Construction will take 63 months according to LG.

## UNITED KINGDOM

### Johnson Matthey sells Research Chemicals

Johnson Matthey says that on September 30th is completed the sale of its Alfa Aesar Research Chemicals business to Thermo Fisher Scientific Inc for £256 million ($410 million) in cash. This completes the transaction announced on June 25th. Commenting on the sale, JM's CEO Robert MacLeod said: "The divestment of the Research Chemicals business is a further step in delivering our long-term strategy to focus the group on growth areas where we can apply our expertise in complex chemistry to create long-term value for our customers." ■



# People

LSB Industries president and CEO **Barry Golsen** has stepped down from his positions, although he will remain on the company's board. In his place, **Daniel D. Greenwell**, lead independent director, will serve as Interim Chief Executive Officer. Mr. Greenwell has been a member of the LSB Board of Directors since 2014 and serves as chairman of the audit committee and a member of the strategic committee of the board.

"On behalf of the Company, I want to thank Barry for his leadership and many contributions to LSB as President and CEO," said Jack E. Golsen, executive chairman. "Barry has played an important role in the growth and success of the Company over the past 38 years. We look forward to continuing to benefit from his insight and industry expertise as a board member. We are also pleased that Dan Greenwell, an experienced executive with over 20 years of industrial, financial and operational experience, will lead the company as we continue to take steps to improve the company's performance and drive enhanced shareholder value."

As a result of his appointment, Mr. Greenwell will no longer serve on the audit committee or as lead independent director of the board, although he will remain a director of the company. Directors **William F. Murdy** and **Richard W. Roedel** have been elected as lead independent director and audit committee chairman, respectively, to replace Mr. Greenwell in those positions.

Additionally, LSB announced the resignations of **David Goss**, executive vice president of operations, and **Michael Tepper**, senior vice president of LSB international operations. **Richard Sanders** has been named interim executive vice president of chemical manufacturing for LSB as from September 29th. Previously a director of the company's board, Sanders will oversee all plant operations and will report to Daniel D. Greenwell. Sanders is a nitrogen fertilizer manufacturing consultant. Previously, he served as vice president of manufacturing for Terra Industries Inc. from 2003 until the acquisition of Terra by CF Industries Holdings, Inc. in April 2010, where he was responsible for Terra's six nitrogen manufacturing facilities' overall operations including production operations, environmental health and safety, project engineering, and technical services. He was also responsible for Terra's annual capital investment program, including major expansion projects, and was previously plant manager of Terra's Verdigris, Oklahoma nitrogen manufacturing complex for nine years prior to this.

Waste-to-biofuels and chemicals producer Enerkem says that **Robert Shaw** has joined its executive team as senior vice president and chief financial officer. He has previously held executive roles in businesses ranging from oil and gas, energy, industrial manufacturing, industrial gases, and consumer products and services, as well as financial and operating executive roles in public and private companies, and was most recently CFO of Southwest Oilfield Products, a privately-held oilfield equipment manufacturer.

Small-scale gas-to-liquids (GTL) developer Velocys has announced the appointment of **Mark Chatterji** as a non-executive director with immediate effect. He has been appointed as chairman of the audit committee in place of Dr Jan Verloop, who will continue to act as a member of that committee. Mark has also been appointed as a member of the remuneration committee and the nominations and governance committee. He was previously CFO and executive vice president commercial of Woodside Petroleum Ltd. during the front end engineering & design (FEED), final investment decision and construction phases of the Pluto LNG plant in Western Australia. Prior to joining Woodside, he was a vice president in the Investment Banking Division of Goldman Sachs in New York. He has also held various positions at Atlantic Richfield, Merrill Lynch, and served in the US Army. Mark is currently a self-employed entrepreneur. He holds an MBA from the Wharton School at the University of Pennsylvania. ■

# Calendar 2015/16

## NOVEMBER

**10-12**
World Methanol Conference,
MUNICH, Germany. Contact: Lynn Urban,
Sales Manager, IHS Events.
Tel: +1 303 397 2801
Email: Lynn.Urban@ihs.com

**23-27**
Training Programme for Urea Engineers,
DOHA, Qatar.
Contact: Mark Brouwer, UreaKnowHow.com
Email: mark.brouwer@ureaknowhow.com

## DECEMBER

**10-11**
IFS Agronomic Conference, CAMBRIDGE, UK
Contact: International Fertiliser Society,
PO Box 12220, Colchester, CO1 9PR, UK.
Tel: +44 1206 851819
Email: secretary@fertiliser-society.org

## FEBRUARY 2016

**29 – March 3**
Nitrogen+Syngas Conference,
BERLIN, Germany.
Contact: CRU Events,
Chancery House, 53-64 Chancery Lane,
London WC2A 1QS, UK.
Tel: +44 20 7903 2444
Fax: +44 20 7903 2432
Email: conferences@crugroup.com

## MARCH

**15-17**
IFA Global Technical Symposium,
NEW DELHI, India.
Contact: IFA Technical & SHE Committee,
28 rue Marbeuf, 75008 Paris, France.
Tel: +33 1 53 93 05 00
Fax: +33 1 53 93 05 45/47
Email: ifa@fertilizer.org

## APRIL

**18-20**
SynGas 2016, TULSA, Oklahoma, USA.
Contact: SynGas Association
Tel: +1 225 922 5000
Web: www.syngasassociation.com

## MAY

**30 – June 1**
84th IFA Annual Conference,
MOSCOW, Russia.
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Email: ifa@fertilizer.org

## JUNE

**23-24**
International Fertilizer Society Meeting,
BUDAPEST, Hungary.
Contact: International Fertiliser Society,
PO Box 12220, Colchester, CO1 9PR, UK.
Tel: +44 1206 851819
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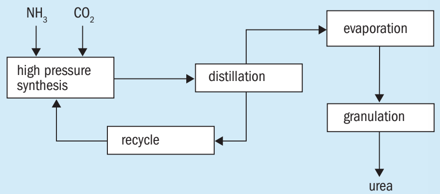
# Plant Manager+

## Problem No. 33 Excessive amount of carbamate solution from recirculation section

**The recirculation or distillation section in a urea plant where unconverted carbamate is separated from the urea/water mixture is a critical section of a urea plant that influences the overall performance of the plant. Too much carbamate solution recycle back to the synthesis section will increase the amount of water in the synthesis and will negatively influence the reactor conversion figures. Fouling in the recirculation section can sometimes cause these operational problems, but how can fouling be identified as the root cause of a problem?**




**Mr Janusz Maćkowski of ZCh "Police" in Poland kicks starts the Round Table discussion with the following problem:** We have quite an old Stamicarbon plant designed in 1976. The gas outlet pipe from the low pressure rectifying column is connected to the gas outlet pipe from the first desorber of the waste water treatment section and together these are connected to the low pressure carbamate condenser (LPCC). There is no reflux condenser. We have a problem with an excessive amount of carbamate solution in the LP carbamate condenser level tank, which leads to overflowing of the level tank. Is it possible (as a result of some kind of equipment damage) that:

- an additional amount of solution goes through the gas pipe from the rectifying column to the LP carbamate condenser?
- and/or an additional amount of solution goes through the gas pipe from the waste water treatment section to the LP carbamate condenser?

Has anyone experienced such a problem?

**Mr Mark Brouwer of UreaKnowHow.com in the Netherlands shares his experience:** Yes, I have seen excessive liquid entrainment from the low pressure rectifier to the LPCC due to fouling (iron oxide scaling) of the holes in the trays in the rectifier. What is the urea content in the carbamate recycle?

**Janusz replies:** We don't have trays in the rectifying column, we have a bed with rings. Some (not all) of the carbamate solution samples show a very high urea content, up to 29 wt-%.

**Mark responds:** But you do have a liquid divider on top of the bed – that is what I meant by trays.

29 wt% is a sure indication of entrainment from the rectifier. Do you have a tangential inlet or sprayer for the liquid inlet of the rectifier?

**Mr Akbar A of Safco in Saudi Arabia shares his view:** We have also experienced the same problem, but with a new Stamicarbon plant where a separate reflux condenser was installed for the desorber column. At the moment when the level of the LPCC level tank shoots up, collect a sample and analyse it for urea. If you find a high urea content, it will be clear that urea solution carryover is occurring from the LP rectifier column only. 29 wt-% urea is too high and may affect the synthesis conditions and HP scrubber, as well as the HPCC equipment.

In a new Stamicarbon urea plant this problem can be solved temporarily by increasing the pressure in the rectifier, but in your case you don't have a separate condenser for the desorber so this increase in pressure will disturb the desorber performance.

Do you have orifice plugs in the tubes at the bottom of the rectifier? If the internal diameter of these orifice pugs has reduced, that can also cause carry over.

*Blocked orifice plugs in circulation heater bottom and top liquid divider blockage.*

**Janusz answers:** Yes, we do have something that could be called a liquid divider over the bed. We don't have a tangential inlet. And we don't have orifice plugs in the heater tubes.

**Mr Easa Norozipour of Khorasan Petrochemical Company in Iran shares his experiences:** We have experienced this problem twice in the low pressure rectifier column. After opening the column we saw that the packing bed was choked with corrosion material. Another one was choked in the heater tubes. The failure of the level transmitter in the rectifier tower can also be another cause.

**Mr Kashif Naseem of SABIC in Saudi Arabia contributes with his experiences:** Possible sources for this is choking of the orifice plugs in the bottom of the rectifying column circulation heater and the packing.

*Packing support plate clogged with corrosion products.*

**Mr Akbar Ali of SABIC/Safco in Saudi Arabia joins the discussion:** For a better understanding of the phenomenon of carry over due to blockage in the top liquid divider and bottom orifice plug, see pictures on previous page, captured after opening the rectifier column following the same problem of solution carry over. After removing these bottlenecks the plant conditions improved.

**Janusz replies:** In my case the heater was clean but the packing support plate was almost completely clogged with corrosion products – see picture above.

**Mr Muhammad Farooq of SABIC/Safco in Saudi Arabia agrees with Mark:** I agree with Mark's observation about the rectifying column. However, a higher recycle rate can be reduced gradually by closing the reactor off gases to the low pressure section provided that the synthesis pressure is in a controllable range, in this scenario the control valve opening should be checked. Although it is not the cause of urea carryover, it may reduce the intensity of the higher recycle rate. ■

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





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# Is the party over for GTL?

Gas to liquids technology promised producers a way of arbitraging the price differential between cheap gas and expensive oil-based products. But with oil prices halved in the past year, has the rationale for GTL production disappeared?

*Above: GTL's high water mark – the Shell Pearl GTL plant in Qatar.*

Over the past two decades gas to liquids production has waxed and waned in popularity with changing global economic conditions. Sasol adapted their coal to liquids slurry phase distillate process for gas to liquids production in 1992, and Shell, partnered by Mitsubishi, Petronas and Sarawak State, produced a demonstrator plant for their own Shell Middle Distillate Synthesis (SMDS) process at Bintulu in Malaysia in 1993, but there was no further activity for some years, as the process was regarded as expensive and low oil prices and high gas prices did not seem to justify the investment required. However, in the early 2000s, as oil prices climbed towards what were then regarded as expensive levels of $40/bbl, Sasol began to look towards cheap sources of gas as a way of licensing their GTL technology. In partnership with oil major Chevron, two project sites were decided upon; at Ras Laffan in Qatar, next to the giant North Field, and at Escravos in Nigeria, where the Nigerian government was engaged in a project to recover and monetise associated gas from its oil production which was being wastefully flared. Although work was slow on the Escravos project, its twin Oryx project in Qatar came in on-budget and almost on schedule. As a result, there was talk that Sasol had 'solved' the problems with GTL, and with oil prices now starting to climb higher and higher there was a slew of new GTL project announcements, most of them in Qatar.

However, the developments coincided with major project activity all around the world as commodity markets moved towards their peak in 2008. With steel expensive and skilled engineers hard to come by, the costs of developing the projects started to spiral, and soon people were backing out of the projects. The only one to come to fruition was Shell's huge Pearl GTL project in Qatar. Nevertheless, in spite of massive cost overruns which brought the project in at close to $20 billion – more than three times the original estimate – Shell still made money on the synthetic fuel it was producing because of the buoyant oil market, and this led other developers to start wondering if there was not, after all, still life in the GTL concept.

The steady fall in US natural gas prices due to shale drilling at the same time as oil and hence gasoline, diesel and naphtha prices remained at record highs kicked off the next GTL project boom. Shell was looking at a 140,000 bbl/d duplicate of Pearl for the Mississippi Delta, and Sasol likewise targeted Louisiana for a 96,000 bbl/d GTL project. Once again, however, the projects coincided with a wave of other new investment, and the high and rising costs of the projects made investors nervous. Shell finally ended development of their project in January 2014, and although Sasol pressed ahead, once oil prices started falling in the second half of that year, they too shelved their Louisiana GTL project, at least for the time being – the company says it may revisit the project in a couple of years. Sasol did also propose a GTL plant for Alberta in Canada, but this has not made much progress in the past two years, and was last reported to be still at the environmental impact phase.

Meanwhile, the ill-fated Escravos project in Nigeria was largely mechanically complete by 2008 in spite of cost overruns and delays, but the gas for it failed to materialise. The project became bogged down in legal cases, and Chevron exited it in 2009. Although the Nigerian government stood by it, it was not until late 2014 when the first train was finally brought onstream, and the project did not achieve full production until April this year. Its final cost was put at $10 billion, more than five times the original estimate.

## Opportunity costs

GTL has had a chequered development history then, with notable successes balanced by equally prominent failures, making it something of a risky investment. And while the balance between oil and gas prices and the large capital cost of the investment are the major factors for GTL developers, as a destination for investment money, beyond the risk premium GTL also has to compete with the opportunity cost of what else can be done with the gas. For the most part this involves export as liquefied natural gas, generally seen as a much safer bet, and LNG prices have also been through a record high period, exacerbated by Japan's shutdown of its nuclear capacity following the Fukushima incident and large scale import of LNG to run power plants in the meantime. LNG has been the most attractive use for large stranded gas fields, and this has helped edge out GTL investment. However, in recent years LNG capacity has been overbuilt, and with the return to production of some Japanese nuclear plants, the price of LNG – which is itself often linked to the price of oil – has more than halved in the past year.

Furthermore, as LNG becomes a more global, more liquid (no pun intended) market, so the link to oil prices is gradually eroding, certainly in spot markets. And as long-term contracts (the initial wave of LNG plants was often built on the basis of 25-year oil-indexed prices for product in order to ameliorate the risk of such high capital cost investments) gradually come to an end, so they are being replaced by more flexible arrangements. If this link between LNG and oil does break down, it might be in the future that a rise in oil prices does not necessarily mean such a correspondingly steep rise in LNG prices, and this might advantage GTL once more. For the moment, however, GTL has been just as disadvantaged by the fall in oil prices as LNG has.

## Central Asia

So if GTL must compete with LNG for investment money in gas development, then perhaps the best location for it is in a landlocked country where there can be no LNG export proposal. Perhaps ideally this would be a region where pipeline schemes have also been fraught with difficulty. This seems to be the reason for a handful of new GTL project proposals for central Asia. Many governments of the region are also reliant on Russia's Gazprom for export routes for their gas and have been looking for ways to add value to their resource-dependent economies and reduce reliance on export pipelines.

Sasol certainly seems to have identified the region as the best bet, with plans for a 38,000 bbl/d joint venture GTL project in Uzbekistan, although as with their Canadian project there has been little movement of late. The Oltin Yol plant is a joint venture with 44.5% participation from Uzbekneftegaz, 25.5% by Sasol (reduced from an initial 44.5%) and 11% by Petronas, with space allocated at the Shurtan industrial complex. However, in 2014 the partners indicated that they had not been able to secure financing for the project, and although an international bank consortium is being formed to fund the plant, project implementation is reportedly "tied to oil prices".

In Turkmenistan, which possesses the world's fourth largest reserves of natural gas, there are two projects under development. The furthest advanced is a collaboration between Haldor Topsoe and Japan's Kawasaki Heavy Industries, together with Turkish construction company Rönesans. Ground was broken last year on the 15,500 bbl/d plant at Ovadan-Depe near the capital of Ashgabad. The plant will be based on Haldor Topsoe's *TIGAS*™ (Topsoe Improved Gasoline Synthesis) technology – the first major commercial reference for this new GTL process. Completion is set for 2018.

South Korean companies Hyundai Engineering and Construction and LG International are also interested in building a large GTL plant at Turkmenbasy in Turkmenistan, 500 km northwest of the capital Ashgabat, with 3.5 bcm per year of gas reportedly allocated to the $2.5 billion project, which will form part of a alrger refining and petrochemical development. Output of diesel and naphtha is put at 600,000 t/a, or around 13,500 bbl/d. A formal agreement was signed with Turkmengas in April 2015.

Finally, in March this year, small scale GTL developer Compact GTL, chaired by ex-BP chief Tony Hayward, unveiled its plans for a GTL plant in Kazakhstan's northwestern region of Aktobe. Kazakhstan has ageing refinery capacity and is a major importer of diesel. The 2,500 bbl/d plant, much smaller than those being developed in neighbouring countries, is a joint project with KazakhOil Aktobe, itself a joint oil and gas production venture between Lukoil, KazMunaiGas and China's Sinopec. KazakhOil will use associated gas from local oil fields, and by avoiding penalties for flaring the gas, the net feedstock cost will in effect be negative. Compact GTL says it hopes it will be a showcase for potential small-scale projects elsewhere. It estimates project costs at $100,00 per installed barrel of capacity, i.e. around $250 million, with operating costs at $15-$20/bbl of diesel produced.



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Table 1: **Global GTL projects – past and future**

| Plant | Developer | Location | Capacity | Onstream |
|---|---|---|---|---|
| Mossgas | Sasol | Mossel Bay, South Africa | 22,000 bbl/d | 1992 |
| SMDS | Shell | Bintulu, Malaysia | 14,700 bbl/d | 1993 |
| Sasolburg | Sasol | Sasolburg, South Africa | 5,600 bbl/d | 2004* |
| Oryx GTL | Sasol/Chevron | Ras Laffan, Qatar | 34,000 bbl/d | 2007 |
| Pearl GTL | Shell | Ras Laffan, Qatar | 140,000 bbl/d | 2012 |
| Escravos GTL | Sasol | Escravos, Nigeria | 34,000 bbl/d | 2014 |
| Juniper GTL | SGC Energia | Lake Charles, Louisiana, USA | 1,100 bbl/d | 2016 |
| Turkmen GTL | Topsoe/KHI | Ashgabat, Turkmenistan | 15,500 bbl/d | 2018 |
| Kazoil Aktobe | Compact GTL | Aktobe, Kazakhstan | 2,500 bbl/d | 2018 |
| Sudapet | Gazohim Techno | Neem, Sudan | 22,000 bbl/d | 2018? |
| TOPC | Hyundai/LG | Turkmenbasy, Turkmenistan | 13,500 bbl/d | 2020? |
| Oltin Yol | Sasol | Shurtan, Uzbekistan | 38,000 bbl/d | 2020? |
| Heartlands | Sasol | Strathcona, Alberta, Canada | 48,000 bbl/d | 2021? |
| Louisiana GTL | Sasol | Lake Charles, Louisiana, USA | 96,000 bbl/d | On hold |

** Built as a CTL plant but switched to gas feed in 2004.*

## Small-scale GTL

Feasibility studies for other large-scale plants have cropped up in all parts of the world – wherever there is surplus, stranded gas – Algeria, Mozambique, Azerbaijan, Papua New Guinea. However, the deep pockets required to finance such ventures and the uncertainties involved mean that at the moment only Central Asia is looking at large GTL developments. The focus on large scale operations was to achieve economies of scale with the capital-intensive plants, which needed a certain scale in order to be viable even at oil prices over $80-90/bbl. But considerable effort has been expended on trying to scale the technology in the opposite direction, to make smaller plants without such eye-watering costs economically viable, using microchannel reactors and modular construction. Some of these have focused on alternative feedstocks such as biomass and gasified municipal waste, but increasingly such technologies are also finding application as small scale GTL plants. Some suggest that small-scale GTL could be the 'game changer' that the industry has been waiting for, allowing producers to take advantage of gas from oilfields that might otherwise be flared or reinjected, or smaller gas fields which are not able to supply the huge volumes of gas required for LNG production or even the volumes needed for ammonia or methanol plants.

Small scale GTL developer Velocys has been working on using shale gas from the Marcellus deposit in Ohio to build a 2,800 bbl/d GTL plant at Ashtabula. However, the project, bought along with developer Pinto Energy by Velocys in 2014, is still at a permit stage, and may have been set back when Velocys suspended its long-standing CEO and driving force Roy Lipski in June 2015 over allegations of "serious misconduct". Lipski subsequently left Velocys in August "by mutual consent", at which time the company said that there was in fact no disciplinary hearing or finding of misconduct, and now insists that things are "business as usual", but its share price has taken a major knock as a result.

Nevertheless, Velocys has also licensed its Fischer-Tropsch technology to Russian GTL developer Gazohim Techno, which built a 100 bbl/d demonstrator plant at Rosenft's Angarsk petrochemical complex in Irkutsk, Siberia using its own partial oxidation process to generate syngas for the process. The demonstrator was completed in 2014, and Gazohim Techno is now looking at a larger plant in Sudan in collaboration with the Sudanese oil ministry.

Meanwhile, as well as its development in Kazakhstan, Compact GTL has built a small-scale (20 bbl/d) demonstrator plant in Brazil for Petrobras, and is now looking at a floating FPSO option, while in Louisiana, Juniper GTL, a 1,100 bbl/d development between SGC Energia, Quintana Minerals Corp. and Calumet Specialty Products, and using technology developed by SGC, is reportedly 70% complete and due for start-up in early 2016, using an existing steam reformer acquired by the consortium to process local natural gas.

And as we noted in our article on 'Small-scale syngas' in *Nitrogen+Syngas* 332 (November/December 2014), other developers like Oberon Fuels and Maverick Synfuels are looking not at Fischer-Tropsch production but instead small-scale methanol or DME production using similar modular reactors.

## Still alive

Reports of the death of GTL, then, to paraphrase Mark Twain, appear to be "greatly exaggerated". Not only is a large scale plant currently under construction in Turkmenistan, there are plans for several others in Central Asia, and Sasol has not yet given up on its projects in Canada and the US, instead pausing for a couple of years to see which way the oil market moves. Moreover while, as Table 1 shows, the first two decades of GTL production belonged to just two technology suppliers – Sasol and Shell – there are now a number of other companies involved in development, and in particular in the development of cheaper, smaller-scale, modular plants which can be more easily integrated into existing facilities such as refineries and gas processing plants or take advantage of small scale, even offshore gas fields. And with the prospect of oil prices rising over the next couple of years and the LNG market slowly decoupling from oil indexed contracts, there could even be space for more large scale projects, where local conditions are favourable. ■







*Ammonia shipping: the SS Navigator Venus.*

PHOTO: NAVIGATOR GAS LTD

The global ammonia market faces many a number of changes, but new US ammonia capacity looks set to be the main disruptive influence.

# A disruptive influence

The global ammonia industry totals around 225 million t/a of capacity, and from that in 2014 it produced around 170 million tonnes of ammonia. However, the merchant market for ammonia is much smaller than this, since most ammonia is produced for captive use, in downstream urea, ammonium nitrate, nitric acid or ammonium phosphate plants. Ammonia transport and storage is complicated by its corrosive and poisonous nature and the fact that it must be cooled to subzero temperatures to liquefy, meaning that in 2014 only 18.5 million tonnes of the compound was traded internationally.

Table 1 shows the balance on a regional basis. The major net importing regions are North America (mainly to feed DAP production in Florida – there is also some transfer from Canada to the USA), Western Europe (for a variety of uses, often industrial/technical), South Asia (mostly to feed Indian DAP and some urea production) and East Asia (Japan, South Korea, Thailand and Taiwan are all net importers, again often for industrial/technical uses). While demand for ammonia ultimately comes mainly from fertilizer applications (about 75% of all ammonia produced), this nitrogen is mostly traded internationally as the more readily portable urea or ammonium nitrates, and so it is the rare non-integrated fertilizer or industrial users who represent the buying side of the market.

Table 1: **World ammonia production, consumption and trade,** 2014, million t/a product

| Region | Production | Export | Import | Consumption | Net imports |
|---|---|---|---|---|---|
| Western Europe | 11.0 | 1.5 | 4.6 | 14.1 | 3.1 |
| Eastern Europe | 5.8 | 0.2 | 0.2 | 5.8 | 0 |
| FSU | 22.0 | 4.4 | 0.3 | 17.9 | -4.1 |
| North America | 15.8 | 1.1 | 5.2 | 19.9 | 4.1 |
| S/Central America | 8.9 | 4.8 | 0.9 | 5.0 | -3.9 |
| Africa | 5.4 | 1.4 | 1.3 | 5.3 | -0.1 |
| Middle East | 15.4 | 3.4 | 1.0 | 13.0 | -2.4 |
| South Asia | 17.2 | 0 | 2.4 | 19.6 | 2.4 |
| East Asia | 65.7 | 1.1 | 2.5 | 67.1 | 1.4 |
| Oceania | 1.7 | 0.5 | 0.1 | 1.3 | -0.4 |

*Source: IFA*

On the export side, the largest volumes come from Trinidad (representing 19% of ammonia trade in 2014) and Russia (16%), with Saudi Arabia, Qatar, Iran, Indonesia, Australia, Algeria, Canada and Ukraine accounting for another 30% of shipments. These top 10 exporters represent around two thirds of all ammonia trade, and are the reason that the FSU, Central America and the Middle East are the major exporting regions in Table 1.

While there is generally overcapacity in nitrogen markets at present, global prices for ammonia have actually defied the fall in urea prices this year, apart from a dip to about $285/t f.o.b. Yuzhnyy in May, but by September this year they had climbed back to $400/t; around the same level as at the start of the year. Although this is down from the levels of $600/t seen a couple of years ago, it nevertheless seems to represent a kind of market floor. But this apparent stability masks the sometimes conflicting influence of a number of factors which are shaping the ammonia market.

## Feedstock

Feedstock cost is the major variable cost item for ammonia production, and the main feedstock for ammonia production is natural gas. Worldwide, natural gas prices have fallen over the past year in tandem with oil prices, especially in regions where gas is still traded on oil-linked contracts, such as in Europe and parts of central Asia, and regions where LNG forms a





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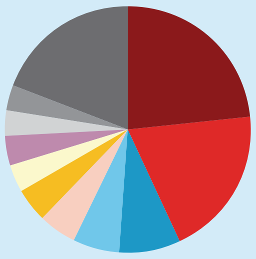
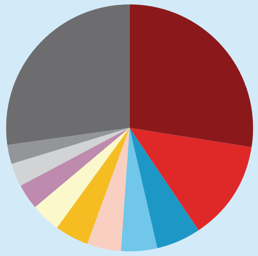
AMMONIA MARKETS

Fig 1: **Top 10 ammonia exporting countries,** 2014




*Source: IFA*

Fig 2: **Top 10 ammonia importing countries,** 2014




*Source: IFA*

significant part of the gas supply, such as in the industrialised parts of East Asia. European gas prices have fallen from around \$10-12.00/MMBtu in 2013-14 to around \$6-7.00/MMBtu in recent months. Gas prices have even fallen in the US, where they were already low due to the shale gas boom. The effect of this on ammonia pricing is ameliorated however by the fact that many ammonia producers worldwide remain on fixed price or otherwise controlled gas price contracts, and so have not in fact necessarily benefited from the fall in gas prices. However, it has eased pressure on European producers.

Furthermore, there are also gas supply constraints which weight upon producers in various countries, including India, Pakistan, Bangladesh, Trinidad, Egypt, Venezuela, and even Algeria – this is one of the factors that has supported ammonia markets over the past couple of years. IFA reckons that around one third of global ammonia capacity is affected by gas constraints of one form or another. China of course is largely insulated from global oil and gas markets by virtue of depending mainly upon coal as feedstock for ammonia production. Here, though, coal prices have also been falling. According to Integer Research, Chinese anthracite coal prices have halved over the past three years, from around \$9.50/MMBtu in early 2012 to \$4.80/MMBtu in August 2015.

## Exchange rates

It is also worth noting that shifting global exchange rates have had a major effect on the profitability of various producers. The precipitate fall in the Russia rouble caused first by sanctions over the occupation of Crimea, followed by the run of low oil prices, has actually helped Russian ammonia exporters immeasurably, with their costs denominated in roubles and their products sold in dollars. The rouble was trading at around 30-35 to the dollar in 2012-14, but now sits at over 60 to the dollar, in effect halving variable costs (including gas costs) for those producers who do not have large dollar-denominated debts.

But it is not just roubles – the dollar has appreciated against many currencies. The Indian rupee has fallen from 45 to the dollar to 65, and worries about emerging markets have led, for example, to a 30% slide in the Indonesian rupiah over the past two years. This is bad news for importers who must pay dollar prices for ammonia, and it is also bad news for exporters whose currency is priced at a fixed exchange rate to the dollar, such as many Middle Eastern producers.

## US capacity building

Undoubtedly one of the greatest medium-term disruptions to the ammonia market has been the return of domestic US ammonia capacity, predicated on cheap domestic shale gas. During the 1990s the US ammonia industry in effect decamped to Trinidad, as domestic gas prices rose in the US, to the extent that Trinidad had been exporting two thirds of US ammonia requirements. But as plants have restarted and new capacity has started to come on-stream, so US imports of ammonia have fallen. US ammonia imports fell from 6.8 million tonnes in 2010 to 5.1 million t/a in 2014, and are set to fall still further as new capacity is completed.

Although much of the new ammonia capacity is integrated into downstream urea and UAN production, new merchant ammonia capacity has come from the ammonia side stream to OCI's Beaumont methanol plant in Texas (240,000 t/a), the Kemper County coal-based power plant another 20,000 t/a, and PCS restarted an idled ammonia plant at Geismar, Louisiana with 495,000 t/a of capacity. In terms of forthcoming ammonia capacity, a large tranche will come from IncitecPivot's new 800,000 t/a ammonia plant at Waggaman Louisiana in 2016, and there are planned expansions at Simplot in Rock Springs (180,000 t/a) and Mosaic at St James parish (320,000 t/a) scheduled for 2017. Also scheduled for that year is the large Yara/BASF ammonia development at Freeport (750,000 t/a). In all around 2.8 million t/a of new ammonia capacity will come on-stream in North America between 2014 and 2018. More is planned, but most of it is based not on expansions by existing producers but new greenfield developments, and at present only one greenfield plant is under construction, OCI's Iowa Fertilizer Co at Wever, which is integrated into downstream urea and UAN production.

## Supply and demand outside the US

It is not just in North America that there is new capacity under development of course, although new merchant capacity is relatively limited. Eurochem has a new standalone ammonia plant planned for Kingisep in Russia, with 960,000 t/a of capacity, due for start-up in 2018. There is a large ammonia-urea complex planned for Nakhodka on Russia's Pacific coast, with potentially another 900,000 t/a of excess ammonia, but the timing of this remains open to question. In Indonesia, there are four ammonia-urea plants under development, some to replace and expand upon older capacity, as well as a single standalone ammonia plant at PT Panca Amara Utama, although this would again replace older capacity which will close. Surplus ammonia availability is expected to reach around 500,000 t/a by 2019. Reduction in available ammonia has come from Saudi Arabia, where the new Safco V urea plant has removed 600,000 t/a of export ammonia capacity, from closures in Japan and Germany, and in particular from the troubles in Ukraine. Ukraine has six ammonia plants, and historically has exported around 1.5 million t/a via the Black Sea. However, the Ukrainian ammonia industry has faced issues firstly with high natural gas prices charged by Russia's Gazprom, and now from the conflict in Ukraine, which has forced the shutdown of the plants at Gorlovka and Severodonetsk. Ukrainian ammonia exports were about 700,000 t/a in 2014, almost half of their value for the proceeding two years.

On the demand side, Morocco is currently engaged in a major expansion of its domestic phosphate production capacity and is looking towards much greater production of downstream phosphate fertilizers, mainly MAP and DAP. Out to 2020, OCP is adding a planned 6 million t/a of phosphate capacity (tonnes $P_2O_5$), which will require a corresponding increase in ammonia imports of about 1.9 million t/a.

## Government policy

Another factor affecting ammonia production and trade is government policy in major producers and consumers. China is the world's largest producer and consumer of ammonia, although its ammonia market tends to be fairly balanced as regards imports and exports, and Chinese nitrogen tends to be exported as urea. As reported at the IFA conference in Istanbul in May this year, China is now looking towards changing its use of nutrients, particularly nitrogen, over-application of which has led to eutrophication and other issues. In December 2014, the government decided to make a historic switch from a concentration purely on food security to one which also covers environmental sustainability. The first fruit of this was a decision to cap fertilizer consumption at its present level out to 2020, making further productivity gains from more efficient use of fertilizer (nutrient use efficiency or NUE), and thereafter, towards 2030, seeing declining use in chemical fertilizers. Rather than the concentration on urea that China has had to date, there will be more investment in nitrogen solutions. The gas and electricity subsidies for fertilizer production are also expected to be withdrawn in 2016. There is already a rationalisation of Chinese ammonia/urea production underway, with older, less efficient plants closing down. The effect on requirements for or availability of ammonia remain hard to gauge – will falling Chinese domestic consumption displace more nitrogen onto world markets, or lead to further plant closures, or some combination of the two?

Meanwhile, in India, which imported 2.4 million tonnes of ammonia in 2014, second only to the United States, the fertilizer subsidy system is also under review. India's ammonia imports are very much driven by production of ammonium phosphates, and phosphates have suffered slightly in recent years form the nutrient based subsidy scheme which has not included urea, allowing an over-concentration on application of urea at the expense of other fertilizers (DAP demand fell by 3 million t/a over the past four years). There has been some subsidy tweaking to try and encourage phosphate demand, but the basic structure seems set to remain the same for the medium term. It is however hoped that a rationalisation of gas prices will lead to more domestic ammonia production, but this is likely to be almost all for domestic urea production, and may not lead to a reduction in imports.

## Disruptive influences

It is new US ammonia capacity which looks set to be the most disruptive influence on the ammonia market over the next few years – an additional 2.8 million t/a will displace imports from Trinidad, and while Caribbean production, both in Trinidad and Venezuela, has recently been constrained by gas availability, some will nevertheless be displaced towards Europe. New demand in Morocco will no doubt absorb some of this, and reduced availability from Ukraine may also offset this slightly. ■





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Regional powerhouse – the huge Ras Laffar complex in Qatar.

# Has the Middle East lost its appeal?

Once the hottest area for new ammonia/urea project development, shortages of gas and political issues have taken the shine off the Middle East in recent years, but is there scope for new development in Iran and potentially elsewhere?

Table 1: **Middle Eastern gas industries, 2014, billion cubic metres/year**

| Country | Production | Consumption | Imports | Exports | Reserves |
|---|---|---|---|---|---|
| Bahrain | 16.9 | 16.9 | - | - | 180 |
| **Egypt** | **48.7** | **48.0** | **2.8** | **3.5** | **1,810** |
| **Iran** | **172.6** | **170.2** | **6.9** | **9.8** | **33,370** |
| Iraq | 1.3 | 1.3 | - | - | 3,520 |
| Kuwait | 16.4 | 20.1 | - | 3.7 | 1,750 |
| **Oman** | **29.0** | **20.5** | **2.1** | **10.6** | **690** |
| **Qatar** | **177.2** | **44.8** | **-** | **123.5** | **24,060** |
| Saudi Arabia | 108.2 | 108.2 | - | | 8,010 |
| UAE | 57.8 | 69.3 | 18.0 | 8.0 | 5,975 |
| **Yemen** | **9.6** | **0.7** | **-** | **8.9** | **260** |

**Bold** *indicates a country in surplus,* *red a country in gas deficit.* *Source: BP*

During the 1990s and 2000s, a reliable destination for new investment in ammonia and urea c apacity was the Middle East. With Europe and India on its doorstep, abundant and cheap natural gas and a favourable investment climate, national oil companies, partnered on occasion by western producers and investors, developed a large and efficient export-oriented nitrogen industry, based on what was often then regarded as "stranded" natural gas, with limited alternative values and in the case of associated gas potentially negative costs associated with flaring. Low, fixed gas prices were the norm, with good margins for ammonia and urea producers. But things have become more complicated as a growing, more integrated gas market globally, especially for liquefied natural gas (LNG), has driven gas prices up and made investment in LNG more attractive than nitrogen or methanol, while rising local demand for gas has crimped availability, at least at the kind of prices that used to be available.

The region still has that gas, as Table 1 shows. The Middle East – including Egypt – holds 44% of the world's natural gas reserves. Two countries alone – Iran and Qatar – have 31% between them. With regional gas production at 19% and consumption at 15.1% of the world's total, respectively, it is also clear that the region has plenty of room for new gas development. However, a look at Table 1 also shows that the situation is not as favourable as it once was. Kuwait and in particular the UAE have slipped into deficit over the past decade, as gas production slows and populations and their energy demands grow. Iraq, Saudi Arabia and Bahrain break even, and Egypt was only just in surplus, and it is reckoned that during 2015 it became a net importer. Egypt had made use of its gas reserves to establish pipeline exports to Jordan, Israel and Syria and LNG export facilities as well as several ammonia-urea plants, and consumption has now caught up with supply and Egypt is looking at gas imports from Israel.

## Gas restrictions

The Middle East, the Arabian Gulf in particular, has seen rapid urbanisation in the past couple of decades. Cities like Abu Dhabi and Dubai have seen their populations triple in 20 years, and high income levels have led to high power demand, especially for air conditioning. Electricity production has depended upon oil and gas-fired generation, but oil-fired capacity is gradually being phased out, especially in Saudi Arabia, as the government seeks to maintain oil export levels from maturing fields and rising domestic consumption of gasoline. All of this is leading to rapidly rising demand for natural gas for power. However, two of the issues with expansion of gas production in the region are – firstly – that much gas production is associated with oil production, and hence crimped by OPEC quotas or – increasingly – used for reinjection into mature oil fields to keep up oil production rates; and secondly, that the gas in the region is often highly acidic/sour, with high proportions of carbon dioxide and hydrogen sulphide.

The upshot has been that gas consumption requirements have prompted both Saudi Arabia and the UAE to begin large scale development of their extensive non-associated sour gas fields. In the Emirate of Abu Dhabi, which holds the lion's share of the UAE's reserves, this has come firstly via the Integrated Gas Development, which processes offshore gas from Umm Shaif/Das Island, as well as associated gas from the Bab onshore oil field and non-associated sour gas from the Habshan fields, and more recently the huge onshore sour gas project at Shah, which is now ramping up to maximum production, processing 1 billion scf/d of highly sour gas (23% $H_2S$) to produce 5.2 bcm/year of sales gas. Further down the line will come the similar sized onshore Bab and Hail projects. Saudi Arabia has major non-associated sour gas processing plants running or under development at Kursaniyah, Wasit and Fadhili, taking gas from offshore sour fields in the Red Sea. Oman has also begun to follow suit, via the Yibal Khuff development and Rabab Harweel Integrated Project. Over the next five years these could collectively be responsible for up to 25 bcm of extra gas production.

Meanwhile, on the Mediterranean side of the region, the discovery of large offshore gas fields in the eastern Mediterranean may also provide a changed environment for Israel and Egypt. In August Eni said that it reckoned the Zohr field which it recently discovered off Egypt was the largest offshore gas field discovered in the Mediterranean, with up to 30 tcf (830 bcm) of gas, potentially increasing Egypt's reserves by up to 50%. The question now must be how quickly can it be brought on-stream, and at what cost?

## Gas pricing

One of the reasons for the shortages of gas in the region has been that gas prices to users have been fixed at very low prices (sometimes less than $1.00/MMBtu). While this may have made sense to encourage development of downstream industries like ammonia, urea and methanol, it only made sense in the context of gas which was otherwise without local use, difficult to export and which in the case of associated gas might otherwise be flared. However, these kind of prices – still charged to most existing regional nitrogen producers – no longer reflect the marginal cost of new gas production, and low fixed gas prices have hence served to crimp new gas exploration and development and so exacerbated shortages. However, charging the full production cost to end users might make some plants far less economical than they are at the moment. The price that the UAE government is paying for gas from the Shah field in Abu Dhabi, for example, is around $5.00/MMBtu – far in excess of typical gas prices in the region – and yet estimates are that the actual cost of extraction is as much as $8.00/MMBtu. Where all of the companies involved are state-owned, the matter is relatively moot, as the government effectively is only deciding at which point it will take the profit – at the wellhead or at the downstream user – but it provides a dilemma for governments who are looking to attract foreign investment – charging realistic gas prices might hurt downstream industries, but subsidising production loses money and discourages investment in gas development.

## Political troubles

While commercial factors have played a part in the cooling of new development, they are not helped by the perception of political instability which the Middle East must grapple with. The Israel/Palestine conflict has always cast a shadow over the region, and even though the last major all-out conflict was 1973, Israeli incursions into Lebanon and Syria, and Iranian backing for militias in occupied territories have left the eastern Mediterranean something of a running sore. Iraq's own pretensions





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to regional dominance under military strongman Saddam Hussein also led to the terrible eight year conflict with Iran during the 1980s and the subsequent invasion of Kuwait in 1990. But undoubtedly the gravest consequences have flowed from the ill-judged US-led invasion of Iraq in 2003, leaving a power vacuum that spiralled into an Iraqi civil war, and which has now destabilised neighbouring Syria. The so-called 'Arab Spring' which began in North Africa led to the overthrow of governments in Egypt and Yemen and the slide of Syria into civil war. And regional rivalries between Saudi Arabia and Iran have fed proxy conflicts in Iraq, Yemen and Syria and agitation even in Bahrain, once a beacon of regional stability. Finally, the potential development of an Iranian nuclear capability has caused concern for Israel, the US and the wider world, and led to years of debilitating international sanctions. Under such circumstances, and with the future uncertain, it is understandable if investment money finds its way elsewhere. Iraq, for example, which still has huge untapped oil and gas reserves, is unlikely to see much in the way of new investment while it continues to be in an effective state of civil war.

Nevertheless, in spite of these issues, the region remains one of the key exporters of ammonia, urea and methanol to Europe and India and beyond, and there are still bright spots for new investment in regional capacity, albeit on a more limited basis than the boom of the previous two decades.

## Saudi Arabia

Saudi Arabia is the world's fifth largest urea exporter, and has been adding capacity steadily. The most recent nitrogen plant to start up in the region was the Saudi Arabian Fertilizer Company's (Safco's) fifth, 1.15 million t/a urea plant. The plant achieved commercial production in July 2015, with exports beginning in August. Ammonia feedstock for the plant comes from other Safco plants at the massive al-Jubail complex, reducing the availability of merchant ammonia from the company by 600,000 t/a. Sabic says that it is also planning to boost urea and methanol production at Jubail by the end of the year by recovering 1,500 t/d of carbon dioxide from its new 500,000 t/a ethylene glycol unit and feeding it into downstream chemical production. The glycol plant will come on-stream later this year. Some of the $CO_2$ will also be purified for food-grade use.

In terms of new project announcements, more ammonia production has come from Saudi Arabia's major attempt to diversify away from reliance on a single commodity – oil – by developing its considerable phosphate rock reserves. The Saudi Mining Corporation (Ma'aden) has already built one major complex to treat phosphates at Ras Al-Khair, 90km north of the major hub of Al Jubail, with 3 million t/a of mono- and di-ammonium phosphate capacity and 400,000 t/a of excess ammonia, and is now in the process of developing a second complex at Umm Wual in the north of the country which will mainly produce processed phosphates, but which will also involve further downstream development at Ras Al-Khair to produce more MAP/DAP.

## Bahrain

Bahrain's Gulf Petrochemical Industries Co (GPIC), which has 400,000 t/a of ammonia and 600,000 t/a of urea capacity at Sitra, is also looking to expand production to add 800,000 t/a of ammonia and 1.3 million t/a of urea capacity, but Bahrain's gas reserves are fully committed and any expansion would depend upon securing new gas, either imported by pipeline from Saudi Arabia, or potentially via LNG imports; Bahrain has been in discussion with Russia's Gazprom over building a 3 million t/a LNG import terminal on the island. Bahrain upped its domestic gas prices to $2.50/MMBtu in April this year, and is introducing phased annual price increases to $4.00/MMBtu by 2022, but the price of imported gas, especially LNG, would of course likely be much higher than this.

## Kuwait

Kuwait's lone foray into syngas-based industries is the Petrochemical Industries Corporation (PIC), which operates three ammonia-urea trains at Shuaiba. The prospects for more gas-based production from Kuwait seems remote now that the country has become a net gas exporter, and there has even been talk that PIC might be interested in exiting the fertilizer industry altogether. Kuwait's economy is dominated by oil, with hydrocarbons making up 95% of Kuwait's exports, and the government is now pursuing a long term strategy which it calls Kuwait Vision 2035, which seeks to reduce the country's reliance on hydrocarbons exports via a series of investments, as well as economic and social reforms, that will transform Kuwait into a regional centre for trade and finance. The 2010-15 National Development Plan formed the first part of this, with major investment in port and other infrastructure, and in February 2015 it was succeeded by the $118 billion Kuwait Development Plan (KDP), which will run to 2020 and involve over 500 projects across all sectors, including $35 billion to be spent by the Kuwait National Petroleum Company (KNPC) to expand oil and gas projects over the next five years. Oil production is to increase to 4 million bbl/d, and there is a major refinery upgrade programme, but PIC's expansions are focusing on olefins, and although increased oil production will bring with it increased gas production, there are no plans for any further downstream use of that gas at present, most of which will likely merely displace imports.

## Qatar

Diminutive Qatar has the second largest regional gas reserves, and the third largest in the world, via its huge offshore North Field, and has turned itself into a gas superpower over the past two decades. However, rather than downstream industries, Qatar has instead focused primarily on gas exports, via the Dolphin pipeline to the UAE, but primarily via the huge LNG export complex at Ras Laffan at the northern tip of the peninsula. Qatargas, with investment from ExxonMobil Mitsui, Marubeni, ConocoPhillips and Total, operates 7 LNG trains with total capacity of 42 million t/a, while the Ras Laffan Gas Company (RasGas) has another 7 trains with 36 million t/a of capacity. Qatar is far and away the world's largest LNG producer and exporter, with 30% of the global market.

Nevertheless, there has been some major downstream development. Ras Laffan also hold's Qatar's unique gas to liquids complex, with the Sasol/Chevron Oryx plant next to the massive 140,000 bbl/d Shell Pearl GTL project. At the moment, however, as our article elsewhere in this issue discusses, there are no plans to expand GTL production here, with falling oil prices taking away much of the incentive for converting gas into liquid products.

The Qatar Fertilizer Company, in which Yara has a 25% stake, has built an impressive array of six ammonia and urea trains







with total capacity of 3.8 million t/a of ammonia and 5.6 million t/a of urea, the most recent of which came on-stream in 2012. With the inauguration of Qafco 6, the company became the world's largest exporter of urea, with around 15% of the global market. However, there are no current plans for any further expansion, and the company has instead looked towards diversifying into melamine and urea-formaldehyde production. By comparison Qatar's methanol industry is relatively modest, consisting of the Qatar Fuel Additives Co (Qafac), in which International Octane is a partner, and its 1 million t/a of methanol and 600,000 t/a of MTBE production.

Indeed, Qatar has had a moratorium on new North Field gas-based developments since about 2008, and as of 2015 this had not been lifted, with the final gas development in the project pipeline, Barzan, due to come on-stream next year. There are indications that project partners would be keen on new developments were that policy to change – Sasol has talked of a new Oryx GTL plant with 100,000 bbl/d of capacity, for example. But at the moment, Qatar has concentrated on consolidating what it has, and in 2015 began a process of restructuring, cost cutting and efficiency improvements in the wake of global oil and gas price falls.

## Egypt

Egypt went on a considerable capacity building spree in the 1990s and 2000s, ending up with major complexes at Alexandria (AlexFert and Abu Qir), Damietta (El Delta and MOPCO) and Suez (EBIC and EFC), totalling 3.9 million t/a of ammonia and 4.2 million t/a capacity. These are in addition to Kima's 1950s vintage electrolysis-based ammonia plant at the Aswan Dam in the south of the country, and the Helwan Fertilizer Company with 400,000 t/a of ammonia and 580,000 t/a of urea capacity, based south of Cairo.

In spite of recent gas curtailments and disruptions caused by civil unrest in the country, capacity building has continued, with two expansions at MOPCO's Damietta site adding 1.4 million t/a of urea capacity, and Kima adding 530,000 t/a of downstream urea capacity planned for 2018. However, as noted above, Egypt's ability to actually fuel all of its capacity is very much dependent upon gas developments in the country, while MOPCO has faced considerable local opposition due to environmental issues with pollution from the existing facilities. Egypt pays gas producers between $2.65-4.10/MMBtu for natural gas, but these prices have been rising.

## Iran

But by far the greatest wild card in the region, in more ways than one, is the Islamic Republic of Iran. Blessed with what are now reckoned to be the largest gas reserves in the world, Iran engaged in a major development programme throughout the 1980s and 90s, and has ended up with about 4.5 million t/a of urea and 5 million t/a of methanol capacity, the latter representing around 5% of the global total. New capacity development has been constrained by Iran's estrangement from the US and its allies and its lack of access to international funding and markets. However. with a new rapprochement with the United States based on common interests in Iraq and a deal over Iran's uranium enrichment programme, the roll-back of United Nations sanctions could see a number of projects which have made slow progress during the sanctions years suddenly on the front burner again.

One of these is a long-running proposal to develop a joint venture ammonia-urea plant with India, which remains the world's largest importer of urea. The project proposal is for a 1.3 million t/a joint venture urea complex to be in the Chahbahar petrochemical zone near the Pakistan border. Previous talks in 2013 about the project had involved three Indian companies; Rashtriya Chemicals and Fertilizers (RCF), Gujarat Narmada Valley Fertilizers & Chemicals (GNFC) and Gujarat State Fertilizers Corporation (GSFC). Iran is said to be looking for a gas price of $2.95/MMBtu, and discussions are on-going, but it is worth noting that gas price arguments killed a previous Indo-Iranian urea project and almost derailed the Oman-India Fertilizer Company.

But this is only the tip of an iceberg of potential new Iranian ammonia-urea capacity. ICIS reckons that there is 7.4 million t/a of ammonia and 10.8 million t/a of urea capacity on the development "slate", with the Iranian National Gas Company (NIGC) listing developments at Masjid, Zanjan, Lordegan, Golestan, Ardabil and Marvdasht, each of 680,000 t/a of ammonia and 1.1 million t/a of urea, or 4.1 million t/a of ammonia and 6.6 million t/a of urea in total.

On the methanol side, there are projects lined up which total as much as 19-20 million t/a, and although this looks wildly optimistic, a recent report by consultancy IHS Inc suggests that there could be 10 million t/a of new Iranian methanol capacity added by 2025 if UN sanctions on the country are lifted, reducing the country's dependence on the Indian and Chinese markets for its exports.

Of course, these plans depend primarily upon access to gas feedstock, making the pace of development heavily dependent on the growth of the Iranian gas industry, and especially on supplies of natural gas from the South Pars gas field, which is being realised in 28 different phases, around half of which are now up and running. It also depends upon access to funding. The Iranian government is likely to be the backer and developer of most of these projects, but its ability to manage to many simultaneously raises many questions about availability of engineers, fabrication capacity etc etc. Still, even if only a fraction make it to fruition in the next five years, they still have the capacity to be extremely disruptive in terms of global markets.

## A maturing industry

The boom years of the Middle East's ammonia and methanol industries, which saw them gain a large slice of market share based on cheap natural gas, are drawing to a close. Expanding populations and power requirements are driving gas prices upwards in most countries, and Saudi Arabia and Qatar are likely to follow suit for new developments. The number of countries importing gas is increasing, and places like the UAE and Egypt may have to decide at what level they can afford to set gas prices in order to justify new exploration and development.

While there are still some plans for new syngas-based developments, many of the current batch of projects are based around diversification or moves into downstream industries, symptomatic of a maturing chemical base. The countries which offer the greatest scope for further development are Qatar and Iran, but this depends upon politics as much as economics – in the case of Qatar decisions about phasing of development of the country's gas reserves and whether LNG is more profitable than GTL, urea or methanol, and in the case of Iran whether the agreement about uranium enrichment holds, sanctions are reversed, and the government is able to secure funding and develop all of the myriad projects which it hopes to. ■






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# Improving safety in ammonia plants

A report on topics discussed at this year's 60th AIChE Safety in Ammonia Plants and Related Facilities Symposium, held in Boston from August 30th – September 5th.

The American Institute of Chemical Engineers (AIChE) has been running its ammonia safety meeting now in one form or another for 60 years. To mark this milestone, this year's keynote address, delivered byAIChE Ammonia Safety Committee members Jim Richardson of Clariant and Venkat Pattabathula of IncitecPivot, looked back at the 60 years of the symposium's history – an abridged version of this paper appeared in the previous issue of the magazine.

## Metallurgy

Operating steel components at high pressures and temperatures and in corrosive environments makes metallurgical hazards – corrosion, fractures and leaks – always one of the most vexed area of ammonia and urea plant operation. Joost Roos of Stamicarbon discussed how proper plugging of corroded and leaking high pressure heat exchanger tubes was necessary to ensure continued safe operation.

Qafco reported on their experience with two waste heat boilers, with issues experienced during re-tubing of the first one, and a corrosion failure of a second after only five years due to stress corrosion cracking caused by excess chlorine in the water.

Fauji Fertilizers in Pakistan discovered cracked weld defects in an ammonia synthesis converter shell on two separate occasions in 2011 and 2012. An investigation by Thielsch Engineering pinpointed hydrogen-induced cracking as the root cause. The converter – suitably patched – was deemed fit for continued service until its scheduled replacement in 2015.

Assessing the remaining life of reformer tubes can be one of the most vital aspects of keeping a reformer running. Chiyoda and H-Scan International looked at the metallurgy of reformer tubes, and how skin temperature measurement can profile remaining life in service. This theme was also carried in a joint paper between Johnson Matthey and PCS Nitrogen in Trinidad, describing tube temperature profiling of the primary reformer of PCS' number two ammonia plant in 2014, and a subsequent rebalancing of burner pressures to better balance heat across the reformer. PCS reported reduced methane slip and inert content in the synthesis loop, and lower fuel consumption overall, as well as a small increase (4 t/d) in ammonia production.

Tube to tubesheet welds are often a source of failure and shutdowns in ammonia plants, and FORCE Technology has developed an automated scanning system based on ultrasonic measurements to identify weld defects. Around 600-800 welds can be examined during a 10 hour shift.

## Mechanical issues

In terms of mechanical failures, Yara reported multiple damage found in an inspection of a horizontal converter basket during an inspection conducted in a plant turnaround. The finding of multiple types of damage resulted in a root cause analysis which concluded most damage was due to too rapid backflow initiated by too rapid pressurisation/depressurisation, and the synloop start-up/shutdown sequence was amended.

Methanex New Zealand drew delegates' attention to the potential for safety incidents arising from disassembly of flanged joints, when some bolts have been removed and extra stress is placed on the remaining bolts. Research using finite element monitoring shows that bolt loads can be reduced by removing the studs in a rotational order rather than the commonly accepted 'star shaped' pattern.

On a similar issue, SKW Piesteritz presented a new flange sealing system, developed by Kempchen Dichtungstechnik GmbH, and featuring a so-called 'superbolt' system by Nord Lock AG, which they have installed on their ammonia plants in Austria.

Casale considered the issue of excessive levels of vibration in pipelines caused by pulsation in reciprocating machinery, which at some points can lead to violent shaking beyond the mechanical resistance of the piping system. These issues can be 'designed out' of the system provided that acoustic simulations and mechanical studies are performed before assembly, and these should also be taken into account during revamps.

Cold temperature embrittlement of steel can lead to costly and dangerous equipment fractures. Baker Engineering and Risk Consultants looked at fracture mechanisms and risk assessment methods which can be used to mitigate them.

## Ammonia storage

With reference to two incidents, one in Lithuania, the other Iran, Dave Pierce of Southern Ionics and John Mason of Agrium explained that the existing API and ISO standards for storage tanks as regards venting, overpressure and underpressure provide good guidance but need to be supplemented by good engineering judgement, with due consideration given to a high integrity protection system (HIPS).

Also on the theme of ammonia tanks, Qafco explained the rationale behind their selection of ammonia tank design for two new 50,000 tonne storage tanks at their Mesaieed site. Siting was also based on a risk assessment of potential emissions from a tank rupture.

## Plant monitoring

OCI described its new barge loading facility in the Netherlands and the connecting ammonia pipelines, which have been equipped with a state of the art thermal imaging ammonia leak detection system and a distributed temperature sensing system.

Nagarjuna Chemicals and Fertilizers Ltd have modified their alarm/safety trip systems to improve plant safety and reliability. Implementing a 2 out of 3 logic voting system allows preventative maintenance of individual trip switches while the plant is in operation.

Johnson Matthey presented a look at the history of ammonia production, with increasing run times placing more emphasis on cleaning process streams to keep catalysts from fouling and deactivation. This can be a challenge when gas feed impurity levels are highly variable. It also involves the effective monitoring of ever-lower impurity levels, with new techniques such as gas chromatography sulphur chemiluminescence detection to measure sulphur levels at ppm levels.

Matthey also detailed work conducted with CF Industries on reformer temperature measurement, balancing and monitoring, in the first case at CF's Courtright, Ontario ammonia plant, where previously undetected hot banding was discovered on reformer tubes, allowing the facility time to prepare for a turnaround for catalyst replacement, and in the second case at the ammonia 1 plant at Verdegris, Oklahoma. Here suspected hot tubes measured cooler than anticipated. A reformer balancing gained four extra months of operations.

BD Energy Systems offer a tube growth monitor to measure linear expansion of reformer tubes in service. This can function as a proxy for tube temperature, and sufficiently precise that overheating conditions can be detected in time to avoid permanent damage. The real time 'temperature' data can also allow other applications to improve reformer performance and tube life management.

Where to best place ammonia monitoring sensors around a plant in order to ensure the safety of workers and nearby residents was the topic of Safer Systems LLC, who have developed a software package with two modules, the first responsible for finding all sensor locations for ant existing hazards, and the second designed for optimising the result by removing unnecessary locations from the list prepared by the first module.

## Risk assessment

Quest Integrity has worked with Yara on the latter's reformer 'best practise' care document, covering monitoring and inspection techniques and giving operators a clear understanding of service-related tube damage mechanisms and the effect of excursions from design conditions, with the aim of reducing the probability of failure of catalyst tubes and a corresponding positive impact on plant reliability.

Glenn Parizot of KBR discussed the role of process safety engineers (PSEs) in a project beyond simple HAZOP studies. PSE's are involved continuously throughout all stages of the design, and must have a thorough understanding of the ammonia process as well as the safety concerns that need to be investigated.

## Other papers

Pardis Petrochemical Co in Iran suffered a catastrophic explosion in the $CO_2$ removal unit of their ammonia plant, resulting from the corrosion-related rupture of an amine line, causing injury to several plant personnel, and the spread and subsequent explosion of hydrogen gas and a fire which followed. A check valve which had been present in the original design had been removed by subcontractors, and had it been present it would have prevented the hydrogen-rich gas from returning from the absorption tower to the rupture point.

GPIC in Bahrain detailed experiences with fouling of the process gas cooler downstream of the secondary reformer. Problems have occurred on the shell side due to boiler feed water quality concerns, as well as on the tube side, from silica and alumina catalyst support from the secondary reformer. The alumina was replaced with corundum balls with low alkali content, but during catalyst replacement in a 2015 turnaround it was noticed that the alumina and silica was being washed out from insulation layers behind the outer layers in spite of vapour barriers, and the secondary reformer design is being studied to overcome migration of alumina from the refractory wall.

During a recent turnaround at Mosaic's St James Ammonia Plant in Louisiana, an incident during low temperature shift catalyst reduction caused pressure drop across the primary reformer to triple. Mosaic and Clarian's Technical Services division worked to determine the cause, which was a coking issue caused by a trip in the process air flow, and remedial action taken to try and save the catalyst charge.

On a happier note, Qafco and Saipem looked at the challenges encountered and overcome during the integration of the new Qafco 6 plant with the Qafco 5 ammonia-urea plants as well as common utilities shared with the Qafco 1-4 site three kilometres away.

Finally, UreaKnowHow.com, the presenters of our regular Plant Manager Plus column (see pages 18-19), has developed a urea incident database with more than 46 entries on it now, which it shares for free among urea producers. Mark Brouwer and Jo Eijkenboom presented some case studies from the database to delegates along with lessons learned. ■



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# Defining the Future

Every 18 months or so, Sud Chemie – now Clariant of course – runs its 'Defining the Future' conference, looking at the future of chemical and petrochemical production. The seventh in the series was held in San Francisco in late August.

The conference covers a wide variety of topics, including ammonia and methanol, hydrogen, styrene, aromatics, olefins, energy, fuels and regulatory issues. The following were some of the highlights as they affect syngas-based industries:

## Changing commercial environments

Theo Jan Simons of McKinsey discussed the impact of falling oil prices on petrochemicals production, as OPEC fights to keep market share in a world oversupplied with oil. Declining oil prices tend to favour industry profitability, he said. However, in the longer term the fall has reduced the incentive for coal and gas to liquids production.

US shale gas has transformed syngas markets, and many have been looking to see whether the fall in oil prices would impact upon shale oil and gas producers. Martha Moore of the American Chemistry Council highlighted the rapid pace of technological development in the US gas industry, allowing more oil and gas to be produced from fewer rigs, cutting costs, and although falling oil prices have reduced the competitiveness of US natural gas liquids (NGLs), the country remains "feedstock advantaged", she said. The ACC is tracking 242 chemical projects in the US, with a total investment value of $149 billion. Much of the expansion is in ethylene and derivatives, but methanol and ammonia and derivatives are also significant growth areas.

China's slowing growth has also been a concern for the industry, but David Xu of McKinsey argued that China is now at a key turning point to transform from a large economy to a great one, if it can make the right policy choices. Growth is likely to subside to a "new normal" of 6-7% per annum over the next decade, he said, for demographic reasons as much as anything, focusing on quality rather than quantity. The rise of new urban consumers and rising household incomes, while the government continues to push market reforms of selected sectors to create more privately held companies and consolidate into 'national champions' that can compete on a global basis. China will still represent 60% of global growth in chemical demand over the next decade, with more downstream diversification likely and opportunities for speciality suppliers.

*Nitrogen+Syngas* editor Richard Hands presented an overview of syngas and its downstream industries. While syngas to power and synthetic natural gas have some market share, and there is interest in Fischer Tropsch liquids from alternative feedstocks, the relatively mature market of ammonia remains the mainstay, based mainly on agricultural demand with the rapidly growing rival of methanol driven by fuel and olefins production. Hydrogen production also continues to advance, mainly to crack difficult feeds in refineries as they face environmental regulations on fuel quality. While natural gas and to a lesser extent coal are the mainstays of syngas feedstocks, $CO_2$ reforming offers massive potential for the longer term future.

## Methanol

Methanol's growth has indeed been phenomenal worldwide, averaging about 11% per year over the past five years, and a forecast that the market for methanol will have swollen to 117 million t/a by 2020. Greg Dolan of the Methanol Institute in the US looked at methanol's versatility – leading some to proclaim the possibility of a 'methanol economy' 10 years ago. Fuel uses now represent 40% of methanol demand, and the potential of using carbon dioxide to produce methanol and hence a carbon neutral fuel has been a draw for policymakers. China now runs 160,000 methanol-powered vehicles (using M85/M100), and is also blending methanol at 10% into its gasoline pool, and there has been interest in Europe in methanol as a clean maritime fuel.

And speaking of methanol and fuels, another growth area for methanol has been via ExxonMobil's methanol to gasoline (MTG) process, and Mitch Hindman of ExxonMobil looked at the process and its commercialisation, from the New Zealand Synfuel plant built in the 1980s, using natural gas as a feed, to the first coal-based development, in 2009, for the Jincheng Anthracite Mining Group (JAMG) in Shanxi Province. The initial 2,500 bbl/d plant is now being joined by a 25,000 bbl/d unit, JAMG-II, due for completion next year. ExxonMobil has also licensed five plants in the US, with a total of over 47,000 bbl/d of capacity. Two are based on cheap shale gas, but interestingly two are coal-based and one biomass-based. ExxonMobil now has a tie-in with Air Liquide's *MegaMethanol* technology for what it calls 'Gas to Gasoline', and is in partnership with Sinopec over a 'next generation' fluid bed process incorporating new process and catalyst developments. A 100 bbl/d pilot plant has now been set up in Henan province, China.

Matthias Stein of Air Liquide discussed the technological side of methanol production, via Air Liquide's successful *Mega-Methanol* technology. Ten such 5,000 t/d plants have been built since 2001, with another five under engineering.

## Alternative propylene production

Olefins production from unconventional sources has become an extremely profitable area for development, with China engaged in large scale methanol to olefins (MTO) development, allowing them to use domestic coal for olefins rather than imported oil. MTO formed an important strand of the conference. Ronald Cascone of Nexant considered 'on purpose propylene' production, where MTO/MTP must compete with metathesis and propane dehydrogenation (PDH) as a source. Nexant expects that 30% of global propylene production will be on purpose by 2025, as conventional production has not kept pace with demand. PDH has been through a major expansion phase in the Middle East, but the focus is now in MTO production in China. New MTP projects are also being developed in 'gas advantaged' regions such as Central Asia and the US.

Thomas Wurzel of Air Liquide looked at the commercialisation of Lurgi's methanol to propylene (MTP) technology, for which Clariant developed the zeolite catalyst, from lab scale tests in the 1990s to the construction of a demonstrator unit at the Tjelbergodden methanol plant in Norway in 2002, and onwards to commercial references. The first plant was licensed in 2006, and by 2010-11 there were two large scale units in China, belonging to Shenhua Ningxia Coal Industry Group and Datang International Power Generation respectively. Looking to the future, Air Liquide are considering integration into downstream propylene-based processes.

Lastly, Jushun Zhang of Sinopec presented 'deep catalytic cracking' (DCC) of heavy oils as an alternative route to propylene production. The technique is highly dependent upon feed – paraffinic feedstocks yield higher fractions of propylene and with higher boiling ranges. Sinopec have tried to get a better grip on the chemistry of propylene formation and inhibition of propylene reconversion in these reactions to develop a DCC-PLUS concept.

## Environmental issues

Needless to say, looking forward environmental issues loom ever larger for the chemical industry. Sustainability is now one of the key buzzwords, and Lenz Kroeck of Clariant described Clariant's commitment to treating sustainability and adding value via sustainability as one of the company's five strategic 'pillars'. The company has set itself a target of reducing water usage by 25% by 2020 (from a 2005 baseline), and waste and greenhouse gas (GHG) emissions by 45% per tonne of product. As these have proved to be achievable before the timescale, a series of higher targets have now been set for 2025.

Catalysts by their nature offer opportunities for energy saving, and Ed Rightor of Dow Chemicals expanded on this topic, noting that by 2030 the world will need 45% more energy, but with a corresponding 40% reduction in GHG emissions. Around 7% of all emissions come from the chemical industry, and eighteen products use 80% of the energy and emit 75% of the industry's GHG footprint. An industry roadmap studied ways to focus on these products to reduce emissions going forward, with the potential to save 15 exojoules (EJ) of energy per year by 2050 and avoid 1 gigatonne of carbon equivalent emissions. However, 'game changers' like low carbon hydrogen or alternative feedstocks are still going to be needed to achieve the savings required.

On that subject, Markus Rarbach of Clariant considered cellulose as an "under-utilised" feedstock resource. Clariant have developed a process they call *sunliquid*, which combines thermal pre-treatment of cellulosic waste with enzyme hydrolysis, ethanol fermentation, energy integration and standardised, modular equipment to produce cellulosic ethanol cheaply enough to compete with ethanol from sugarcane. A 1,000 t/a demonstration plant has been up and running from 2012, and the process is now moving to a full commercial plant.

Christian von Olhausen of Sunfire presented what he called 'power to liquids' – a solid oxide fuel cell which can run reversibly, generating hydrogen and carbon monoxide when consuming power, with high energy efficiency (ca 70%). The syngas is then processed conventionally to Fischer-Tropsch lqiuids. It offers an alternative for renewable power sources when they are producing energy at times when it is not required, as well as the ability to supply back-up power when running the fuel cell conventionally in electricity generation mode.

## Methane to liquids

A slightly offbeat technology is offered by locally San Francisco-based Siluria Technologies, as described by Edward Dineen. Rather than the conventional gas reforming and Fischer-Tropsch polymerisation or methanol to gasoline conversion, Siluria have developed a process which uses oxidative coupling of methane to produce polymer grade ethylene in a fixed bed adiabatic axial reactor, and a downstream way of producing gasoline and diesel from this ethylene if required. At the moment the focus is on modular add-ons to existing industrial facilities such as refineries and petrochemical plants, but longer term the vision is for world-scale gas to liquids plants using the technology. Linde will begin marketing the ethylene technology for commercial scale production at the end of this year.

## 100th AmoMax reference

Finally, Clariant celebrated its 100th reference for its AmoMax ammonia production catalyst at the event – at the Iowa Fertilizer Project in the US. Taylor Archer of Clariant interviewed Darrell Allmann Taylor of Iowa Fertilizers about the progress with the project, and some of the thinking behind it. The project includes a 2,200 t/d KBR ammonia plant, a 2,200 t/d Stamicarbon pool reactor urea plan, and a 4,300 t/d Uhde UAN plant, and is expecting mechanical completion in late 2015. ■



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# Syngas project listing 2015

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

| Contractor | Licensor | Company | Location | Product | mt/d | Status | Start-up date |
|---|---|---|---|---|---|---|---|
| **BRAZIL** | | | | | | | |
| Toyo-Setal | Haldor Topsoe | Petrobras | Rio de Janeiro | Hydrogen | 2x125,000 | UC | 2020? |
| **CANADA** | | | | | | | |
| n.a. | Sasol | Sasol | Strathcona, AB | GTL | 7,400 | P | 2021 |
| **CHINA** | | | | | | | |
| n.a. | JM/Davy | Mengda New Energy | Inner Mongolia | Methanol/MTO | 2,030 | C | 2015 |
| n.a. | JM/Davy | China Shenhua CTL | Urumqi, Xinjiang | Methanol | 5,500 | UC | 2015 |
| n.a. | JM/Davy | Suxin Energy Hefeng | Tacheng, Xinjiang | SNG | 2 bcm/a | UC | 2016 |
| Hebei Construction | n.a. | Inner Mongolia Beikong | Ordos, Inner Mongolia | SNG | n.a. | UC | 2016 |
| n.a. | n.a. | Sinopec Xinjiang | Zhundong, Xinjiang | SNG | 8 bcm/a | BE | 2018 |
| Casale | Casale | Shanxi Jinmei Huayu | Jincheng, Shanxi | Methanol | 4,000 | UC | 2016 |
| Casale | Casale | Xinneng Energy Ltd | Erdos, Mongolia | Methanol | 2,000 | UC | 2016 |
| Casale | Casale | Xinjiang Xinye | Wujiaqu, Xinjiang | Methanol | 2,000 | UC | 2015 |
| Casale | Casale | Fugu Hengyuan | Gushan, Shaanxi | Methanol | 1,820 | UC | 2015 |
| n.a. | n.a. | Erdos Sanwei | Inner Mongolia | Methanol/MTO | 1,200 | C | 2015 |
| n.a. | n.a. | Qinghai Salt Lake | Golmud, Qinghai | Methanol/MTO | 3,000 | UC | 2015 |
| n.a. | n.a. | Sinopec Henan | Hebi, Henan | Methanol/MTO | 5,500 | BE | 2016 |
| n.a. | n.a. | Gansu Pingliang | Pingliang, Gansu | Methanol/MTO | 5,500 | DE | 2017 |
| **ICELAND** | | | | | | | |
| n.a. | n.a. | Carbon Recycling | Svartsengi | Methanol | 12 | RE | 2015 |
| **INDIA** | | | | | | | |
| Engineers India Ltd | n.a. | Assam Petrochemicals | Namrup | Methanol | 500 | UC | 2017 |
| **IRAN** | | | | | | | |
| Namvaran/IIND | JM/Davy | Kharg Petrochemical Co | Kharg Island | Methanol | 4,350 | UC | 2017 |
| Namvaran | Haldor Topsoe | Marjan Petrochemical | Marjan | Methanol | 4,850 | UC | 2016 |
| TCC | Haldor Topsoe | MEKPCO | Pars | Methanol | 4,850 | DE | n.a. |
| PIDEC | Casale | Kaveh Methanol | Bander Dayyer | Methanol | 7,000 | UC | 2015 |
| PIDEC | Casale | Apadana Methanol | Assaluyeh | Methanol | 5,000 | UC | 2017 |
| **KAZAKHSTAN** | | | | | | | |
| n.a. | n.a. | CaspOilGas | Kuryk | Methanol | n.a. | P | n.a. |
| n.a. | Compact GTL | Kazoil | Aktobe | GTL | 350 | DE | 2018 |

**KEY**

*BE: Basic engineering*
*C: Completed/commissioning*
*CA: Contract awarded*
*DE: Design engineering*
*FS: Feasibility study*
*n.a.: Information not available*
*P: Planned/proposed*
*RE: Revamp*
*UC: Under construction*

*Conversion:*
*1 t/d of hydrogen = 464 $Nm^3/h$*
*1 t/d of natural gas = 1,400 $Nm^3/d$*





| Contractor | Licensor | Company | Location | Product | mt/d | Status | Start-up date |
|---|---|---|---|---|---|---|---|
| **NIGERIA** | | | | | | | |
| Foster Wheeler | Sasol | SasolChevron | Escravos | GTL | 4,800 | C | 2015 |
| n.a. | Haldor Topsoe | Brass Fertilizer Co | Brass Island | Methanol | 5,000 | CA | 2018 |
| **PAPUA NEW GUINEA** | | | | | | | |
| n.a. | n.a. | Sojitz/NPCP | West Papua | Methanol | 3,000 | P | 2020 |
| **PERU** | | | | | | | |
| n.a. | Haldor Topsoe | Petroperu | Talara | Hydrogen | 72 | DE | 2019 |
| **QATAR** | | | | | | | |
| Casale | Casale/MHI | Qafac | Mesaieed | Methanol | 3,160 | RE | 2015 |
| **RUSSIA** | | | | | | | |
| n.a. | Haldor Topsoe | Shchekinoazot | Shchekino | Ammonia/Methanol | 1,360 | UC | 2018 |
| ThyssenKrupp IS | ThyssenKrupp IS | Shchekinoazot | Shchekino | DME | 60 | UC | 2016 |
| NIIK/MHI | Haldor Topsoe | JSC Ammoniy | Mendeleevsk | Ammonia/Methanol | 2,050 | UC | 2016 |
| n.a. | Linde | PSC TAIF-NK | Nizhnekamsk | Hydrogen | 2 x 240 | UC | 2015 |
| Casale | Casale | Metafrax | Gubakha, Perm | Methanol | 2,200 | RE | 2015 |
| n.a. | Linde | Bashneft | Ufa | Hydrogen | 420 | C | 2015 |
| **TRINIDAD AND TOBAGO** | | | | | | | |
| n.a. | MGC | Caribbean Gas Chemical | La Brea | Methanol | 3,000 | DE | 2018 |
| n.a. | MGC | Caribbean Gas Chemical | La Brea | DME | 300 | DE | 2018 |
| **TURKMENISTAN** | | | | | | | |
| n.a. | Haldor Topsoe | Turkmen GTL | Ashgabat | GTL | 2,200 | BE | 2018 |
| **UNITED STATES** | | | | | | | |
| n.a. Delayed | Haldor Topsoe | Valero | Lake Charles, LA | Methanol | 4,200 | DE | |
| Mitsui | Haldor Topsoe | Celanese | Clear Lake, TX | Methanol | 3,700 | C | 2015 |
| Fluor | JM/Davy | South Louisiana Methanol | St James Parish, LA | Methanol | 5,000 | DE | 2018 |
| Jacobs | (plant relocation) | Methanex | Geismar, LA | Methanol | 3,000 | RE | 2016 |
| n.a. | Air Liquide | Natgasoline LLC | Beaumont, TX | Methanol | 5,000 | DE | 2017 |
| n.a. | ExxonMobil | Natgasoline LLC | Beaumont, TX | MTG | 3,000 | DE | 2017 |
| Foster Wheeler | ExxonMobil | ZeoGas | n.a. | MTG | 2,000 | FS | n.a. |
| Proman | JM/Davy | Big Lake Fuels | Lake Charles, LA | Methanol/MTG | 4,200 | DE | 2018 |
| n.a. | n.a. | Northwest Innovation | Clatskanie, OR | Methanol | 3,000 | P | 2019 |
| n.a. | n.a. | Northwest Innovation | Kalama, WA | Methanol | 3,000 | P | 2019 |
| n.a. | n.a. | Northwest Innovation | Tacoma, WA | Methanol | 3,000 | P | 2019 |
| n.a. | Red Rock | Red Rock biofuels | Oregon | BTL | 500 | P | n.a. |
| n.a. | Linde | Husky Energy | Lima, OH | Hydrogen | 5,500 | UC | 2016 |
| n.a. | Air Liquide | BASF | Freeport, TX | Methanol/MTP | 1,400 | P | 2019 |
| n.a. | G2X Energy | G2X Energy | Pampa, TX | Methanol | 200 | C | 2015 |
| GNPD | SGC Energia | Juniper GTL | Lake Charles, LA | GTL | 150 | UC | 2016 |
| **UZBEKISTAN** | | | | | | | |
| n.a. | Sasol | Oltin Yo'l GTL | Kashkadarya | GTL | 5,000 | DE | 2020 |



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# Product diversification

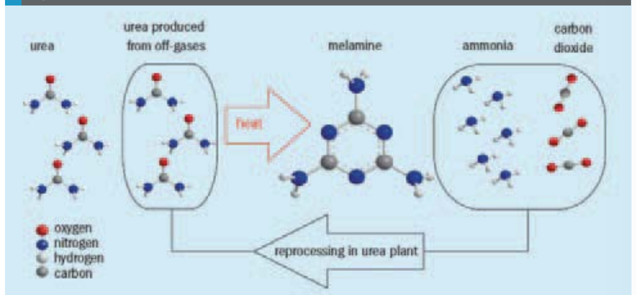
Advances in process technology and improvements in the energy efficiency of plants widens the options for ammonia, urea and methanol producers to diversify into new downstream products such as melamine and to benefit from greater process integration.

Melamine offers urea producers a very interesting business opportunity to diversify by extending the nitrogen value chain, starting from hydrocarbons, with a new product having a strong market growth potential.

Melamine is a chemical made directly from urea with applications in high end plastic products such as moulding compounds, decorative laminates, adhesives for the woodwork industry, coating resins, concrete plasticizers and resins for paper finishing.

Furthermore, the off-gases generated in the melamine plant can be recycled back to the urea plant where they are converted back into urea thus making a melamine plant perfectly integrated within a fertilizer complex.

Fig 1: Melamine + urea integration concept




Source: Eurotecnica

## Eurotecnica melamine plants

The Eurotecnica Group is known around the world as a leading technology provider, designer and implementer of melamine production plants based on its proprietary Euromel® melamine process. The brand is registered in more than 45 countries and represents 85% of the world's melamine consumption. Twenty melamine plants have been built around the world on the basis of this technology, in total accounting for more than 610,000 t/a of licensed nameplate capacity.

## Euromel® melamine process

The Euromel® melamine process is characterised by its zero pollution, top product quality, safety, reliability and easy integration with any urea plant thanks to the pressure and composition of the off-gases, which can be adapted to the needs of any urea plant.

Originally introduced in the 1960s by Allied Chemical, USA, and later transferred to Eurotecnica, Italy, this high-pressure non-catalytic technology was ahead of its time, innovative and the first high-pressure melamine technology ever implemented in a commercial scale plant. Over the years, the technology has gone through a series of improvements. From the first plant, built in Kuwait in the late 1970s, to the latest one, a 60,000 t/a single-reactor/single-purification line under construction in China, the focus of Eurotecnica has been on the elimination of any polluting outputs (currently the only technology releasing no solid or liquid waste streams at process battery limits), the reduction of opex and capex, the maximisation of reliability and on-stream factor. The proven design and the wide experience in the melamine sector has played an important role in the success of this technology, which favours simple technical solutions and robust mechanical components over unnecessarily sophisticated and therefore sometimes troublesome ones.

## Melamine plant integration in a fertilizer complex

There are various challenges to be addressed when introducing a melamine plant in a fertilizer complex, such as minimisation of the variable cost of raw materials, minimisation of the investment required and the impact on urea production.

To solve these issues Eurotecnica has patented and implemented solutions like the "zero water return" concept allowing full recycle of off-gases to the urea plant without sending any additional water to the urea synthesis loop.

## Effect on raw materials cost

Looking at the general reaction to produce melamine from urea the amount of by-product generated (off-gases containing ammonia and $CO_2$) is larger than the amount of melamine produced per tonne of urea (Fig. 1). It is clear that these off-gases need to be recycled somehow, to exploit their nitrogen content and transform it back into urea. This allows melamine to be produced with a typical raw material requirement of 1.428 tonnes of urea per tonne of melamine. A proper integration poses several challenges and limits the ratio of capacities between urea and melamine plants to somewhere around 10:1.

When the integration is not carried out properly, in some cases just because the urea plant does not allow such integration without an extremely costly intervention, the result is that the capacity of the urea plant is reduced and the net output of urea from the complex is reduced, resulting in an uncompetitive situation in terms of the variable costs for raw materials for melamine production (i.e. >1.428 tonne urea/tonne of melamine).

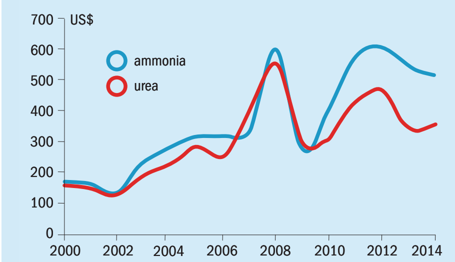
In some cases, when additional ammonia and $CO_2$ are available and reliable technical solutions exist with a reasonable investment, the integration of a new melamine plant can involve revamping the urea plant, aimed at keeping the output of urea unchanged, thus not affecting the finishing section of the urea plant.

If this is achieved the complex will produce the same amount of urea as before, plus melamine, but less ammonia will be available for sale. This allows melamine to be produced with a raw material specific consumption of 0.81 tonnes of ammonia per tonne of melamine.

## Economic analysis

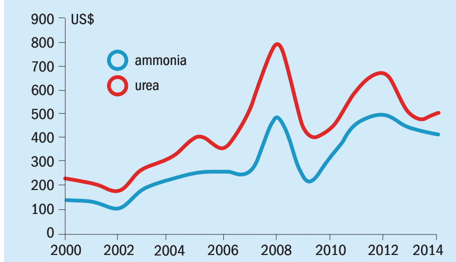
The prices of ammonia and urea have fluctuated widely over the last 15 years (Fig. 2). When comparing the production costs due to raw materials of an "integrated" plant with the costs of a "revamped" plant able to achieve 0.81 tonnes of ammonia per tonne of melamine there is a clear advantage for a revamp versus a simple integration, provided of course that it is technically feasible and that the depreciation of the additional investment involved does not offset the advantage (see Fig. 3).

Fig 2: Historical urea and ammonia prices 2000-2014, US$




Source: Eurotecnica

Fig 3: Historic variable costs, integrated vs revamped plant




Source: Eurotecnica

## The stand-alone concept

This analysis prompted Eurotecnica to study the concept of a "stand-alone" melamine plant, i.e. a plant including a urea and off-gas recycle section within the melamine plant itself and therefore producing melamine from ammonia and $CO_2$ (see Fig. 4).

A stand-alone plant is an attractive opportunity for:

- ammonia producers with $CO_2$ available who are willing to go downstream without producing urea;
- independent investors willing to produce melamine and having access to ammonia and $CO_2$ produced by a neighbouring plant.

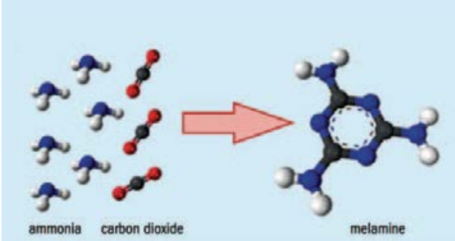
However, generally speaking the stand-alone concept is not so attractive for a traditional urea producer, because the investment is higher than what is normally required for integration or revamping. The additional investment has to be taken into serious account because it partially offsets (in terms of higher depreciation) the advantage of having ammonia as raw material (see Fig. 5).

Where the opportunity for a stand-alone concept exists, Eurotecnica's approach is to team up with leading urea technology providers such as Stamicarbon, Saipem and Toyo to provide investors with a reliable, efficient, cost-effective and low-risk configuration.

A poorly designed unit would jeopardise the continuous supply of urea feedstock to the melamine plant, which would affect the performance of the entire melamine complex. The small urea unit attached to the melamine plant is a delicate unit, requiring experienced designers and proper materials of selection.

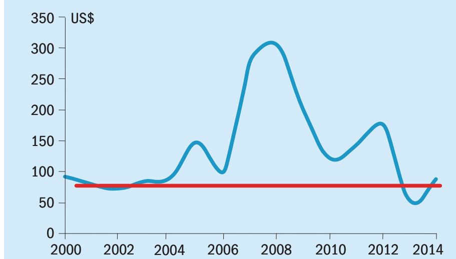
Eurotecnica, acting as a single point responsibility, is a guarantee for the optimal implementation of a stand-alone melamine

Fig 4: Stand-alone concept: melamine from $NH_3$ and $CO_2$




Source: Eurotecnica

Fig 5: Economic advantage for the stand-alone concept




Source: Eurotecnica



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plant. Investor's freedom to choose the preferred urea technology provider among those cited is also a major advantage.

The main disadvantage of the stand-alone plant compared to the integration and revamping of a urea plant is the investment cost as well as the footprint.

However, disadvantages also exist when considering the integration and revamping of a urea plant because of the introduction of a melamine plant:

- It may not be technically feasible or the investment may be too high to achieve the desired raw materials cost advantage because of the status of the existing urea plant and the ratio of capacities between urea and melamine.
- Shutdown(s) will be needed to implement the integration/revamp, which will mean loss of production.
- There is a limit to further expand the melamine capacity to become a global leader in the melamine market.
- If there is no revamp either because of unavailability of additional ammonia and $CO_2$ or because the urea plant is not suitable for an extensive retrofitting, the raw material cost will be based on an unfavourable 1,428 t urea / t melamine.
- If the integration is carried out without due care and diligence it may lead to even higher raw material costs.

The question is, does an option exist that provides a seamless introduction of a melamine plant in a fertilizer complex without the need for any modifications, nor any kind of shutdown, nor any constraint in the capacity ratio between melamine and urea? According to Eurotecnica, such an option does exist and has been invented and patented by Eurotecnica. More details will be made available in early 2016.

## Casale urea and melamine experience

Casale is a world leader in the urea field and is the only licensor with demonstrated capability of integrating melamine and urea plants together with the debottlenecking of the urea plant to minimise the impact of the melamine off-gases or to increase the production.

In 2013, Casale acquired the melamine technology portfolio of Borealis as part of a strategic plan aimed at strengthening the offer of its core technologies and know-how with a new product that has strong synergy with the company's current product portfolio and market base.

In February 2015, Casale signed its first melamine contract since the acquisition for a 40,000 t/a melamine plant and for a urea unit with a capacity equal to the gross urea requirement for the melamine production plus 50,000 t/a of additional molten urea capacity for existing melamine plants. The melamine plant will be fully based on Casale's Low Energy Melamine (LEM™) process (formerly Borealis HP melamine technology).

In Casale's LEM™ process, urea is converted directly into melamine at high pressure without the use of any catalyst, unlike melamine processes which are operated at lower pressure.

The differentiating features of Casale LEM™ process are:

**Energy efficiency**
- less energy (steam and gas) consumption
- less green house gases ($CO_2$)
- heat of condensation recovery

**Melamine conversion efficiency**
- reduced feedstock cost for melamine production
- frees up additional urea volumes for sales
- reduced energy demand for reprocessing of off-gas into urea

**Urea yield from off-gas**
- water free off-gas as additional feedstock for urea production ("debottlenecking effect")
- off-gas available at much higher pressure and temperature
- simple integration of off-gas stream into high pressure section of urea plant

One of the main features of this project is that the plant is a completely stand-alone unit, using ammonia and $CO_2$ directly as feed, which will be processed in a dedicated melamine off-gas treatment section, where they will be transformed into urea before being sent to the melamine synthesis section. This project is an example of Casale technology integration combining its well referenced experience in the urea field with its recently acquired melamine technology from Borealis. Casale has studied and developed an optimised integrated process, which produces melamine from ammonia and carbon dioxide taking advantage of the superior process features of the recently acquired HP LEM™ process and the advanced concept of the urea split flow and full condenser process. The new plant is slated to be commissioned in 2018.

### Casale urea-melamine integration case studies

Casale has good experience in integrating different types of melamine plants with urea plants and has performed numerous studies for the integration of melamine plants with existing urea plants, some of which have been implemented.

The following case studies represent some of the other significant projects and studies that Casale has carried out:

- **Case 1:** Integration of a urea plant with $CO_2$ stripping process with a Eurotecnica melamine plant without additional increase of final urea production.
- **Case 2:** Integration of a urea plant with $CO_2$ stripping process with a Agrolinz melamine plant with an additional increase of urea production.
- **Case 3:** Integration of a urea plant with total recycle technology with a Eurotecnica melamine plant without additional increase of urea production.

### Case 1

The first case is a $CO_2$ stripping urea plant with an original plant capacity of 1,500 t/d that was integrated with a 20,000 t/a melamine plant designed with Eurotecnica technology (see Fig. 6). The integration with this type of melamine unit leads to an increase of urea synthesis capacity of about 13% and an increase of water recycled to the loop of about 15% compared to the figures of a stand-alone plant.

It is therefore fundamental to prevent or minimise any further introduction of water into the system in order to avoid detrimental condition of the urea reactor in the urea synthesis loop and to maximise the performance of the urea reactor with minimal investment cost.

Casale's approach to the first problem was to maximise the utilisation of the water already present in the process in order to ensure the proper condensation of the melamine off-gases. A new condensation section working at a pressure of about 18 bar was realised.

The new section was provided with a condenser and a closed circuit cooling system necessary to remove the condensation heat of the melamine off-gases. The necessary amount of condensing water is provided by the carbamate recycled back from the existing LP recycling section.

The condensate from the new section feeds the existing HP carbamate pumps that recycle the solution to the HP loop.







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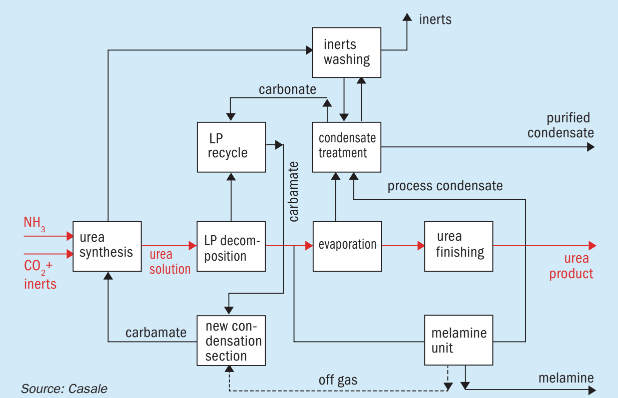
Fig 6: **Urea $CO_2$ stripping integrated with Eurotecnica melamine**




*Source: Casale*

The solution condensed at higher pressure has a lower content of water compared to that at lower pressure; therefore the carbamate that is recycled will contain a lower percentage of water compared to the original one. For reference, a typical concentration of water in carbamate of a stand-alone plant is 33 wt-% which is reduced to 30 wt-% after melamine integration.

Table 1 provides a comparison of the carbamate parameters before and after the integration.

The second problem, improving the performance of the reactor, has been achieved by adopting Casale's proprietary high efficiency trays that, despite the increased $H_2O/CO_2$ ratio in the reactor, increased the reactor efficiency by more than 1.5%.

Table 2 compares the performance figures before and after the melamine integration project.

It is clear that this type of scheme can only be applied if the ratio between the urea plant capacity and melamine plant capacity is sufficiently high to prevent an extremely high $H_2O/CO_2$ ratio in the reactor that would otherwise drastically depress the urea reaction, and therefore, the synthesis efficiency. Alternatively, a more significant modification of the HP loop would be necessary in order to compensate the reactor efficiency reduction.

Table 1: **Carbamate parameters before and after integration**

| Parameters | Before | After | Increase |
|---|---|---|---|
| Synthesis capacity, t/d | 1,500 | 1700 | 13% |
| Carbamate recycle, kg/h | 37,500 | 50,000 | 34% |
| Specific carbamate recycle kg/t of urea | 595.4 | 705.7 | 19% |
| Water flow recycle, kg/h | 12,300 | 15,000 | 22% |
| Specific water flow recycle kg/t of urea | 196.5 | 211.7 | 7.7% |

Table 2: **Performance before and after melamine integration**

| | Before | After |
|---|---|---|
| Total urea production, t/d | 1500 | 1700 |
| Urea prills production, t/d | 1500 | 1500 |
| Urea solution production, t/d | - | 200 |
| N/C ratio | 3.1 | 3.2 |
| H/C ratio | 0.5 | 0.56 |
| Reactor conversion, wt-% | 58.7 | 60.4 |
| Steam consumption, kg/t | 840 | 830 |

**New installation/modification**

The main goal of the project was to maintain the total prills production and integrate the melamine plant with the urea plant to limit the investment cost of the project.

This objective was achieved by adopting the following modifications:

- new high efficiency trays in urea reactor;
- new circulation water cooler for HP scrubber;
- additional surfaces on recirculation heater and LP carbamate condenser;
- additional atmospheric evaporator and condenser;
- melamine feed pumps.

In addition, a new off-gas condensation section was added consisting of LP carbamate pumps and an off-gas condenser with relevant tempered cooling water system.

## Case 2

This case refers to a $CO_2$ stripping urea plant with an original capacity of 1,500 t/d that was running at an overall capacity of 1,800 t/d. The client asked Casale to increase the urea capacity to 1,900 t/d and to integrate it with a 80,000 t/a melamine plant designed with Agrolinz technology (Fig. 7). Integration with this type of melamine unit leads to an increase of urea synthesis capacity of about 50% and a 25% increase of water recycled to the loop compared to the figures for a stand-alone plant.

In this particular case the off-gases from the melamine unit are recycled in liquid form since the condensation is performed within melamine battery limits.

This case has a lower impact in terms of recycled water compared to the previous one. In fact the off-gases from the melamine unit are water-free and produced at high pressure, and therefore, with a lower water requirement necessary for their condensation. On the other hand, in view of the very high capacity of the melamine unit and the required revamping of the urea production, the existing equipment of the HP loop would not be in a position to handle such a high output (i.e. 2,700 t/d) with the present scheme.

Casale selected an approach that retained all the equipment of the HP loop except for the HP carbamate condenser that needed to be replaced in any case since it was close to the end of its life. The urea reactor was modified by installing Casale high efficiency trays that enable an increase of conversion of about 1.5% even if the reactor is running with a higher $H_2O/CO_2$ ratio (0.52 compared to 0.43 for a stand alone plant).

In addition, Casale introduced its Split Flow™ and Full Condenser™ that require a much smaller HP carbamate condenser compared to a traditional $CO_2$ stripping plant. The surface of the new condenser is only 10% larger than the existing one even if the loop capacity has increased by 50%.

Moreover, thanks to the Split Flow™ technology, only one third of the inerts volume fed to the plant is introduced in the urea reactor with a consequent improvement of the reactor performance.

It remains only a limiting factor in the HP loop for the achievement of the new synthesis capacity. In addition, Casale provided a new section equipped with a decomposer and condenser working at a pressure of about 20 bar in parallel to the existing stripper.

About 25% of the liquid leaving the reactor is split into the new section. The bottom of the decomposer joins the bottom of the stripper and feeds the LP recirculation following the original routing. This modification leads to a moderate increase of carbamate recycle, but prevents having to replace the stripper, which is a costly piece of equipment of the urea plant.

Table 3 compares some basic figures for the plants before and after melamine integration and capacity increase.

As is clear from table 3, the specific carbamate flow recycle has increased significantly by more than 50% due to the high melamine plant capacity and the introduction of the parallel unit. On the other hand, despite the huge carbamate increase, the specific water recycle has been limited to an increase of only 9%.

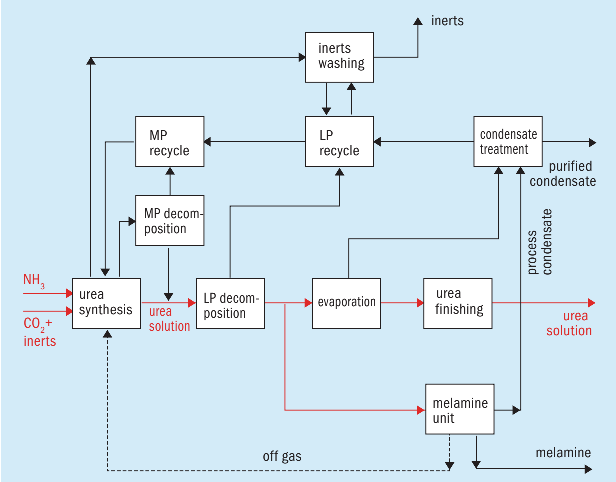
In view of the high capacity of the melamine unit (80,000 t/a) and the requirement to increase the final output of the urea product, the project is clearly of a much bigger magnitude compared to Case 1. Therefore, the modifications and additions are much more extensive. Despite this the fundamental target of minimising the addition of new HP equipment was achieved, only the HP condenser that was already at the end of its working life was replaced. Casale provided a smaller HP condenser compared to that for a traditional plant of this capacity plus the additional parallel section running at about 20 bar.

The main modifications are listed below:

- high efficiency trays in the reactor;
- new HP carbamate condenser (full condenser);
- parallel section decomposer and condenser with relevant tempered water system;
- additional HP ammonia and carbamate pumps;
- additional $CO_2$ compressor;
- new recirculation heater and additional LP condenser;
- melamine feed pumps;
- new distillation column;
- high efficiency trays for urea hydrolyser;
- additional pumping capacity of waste-water treatment unit.

The off-gas condensation section was outside of Casale design.

Fig 7: **Urea $CO_2$ stripping integrated with Agrolinz melamine**




*Source: Casale*

Table 3: **Comparison of basic figures before and after melamine integration and capacity increase**

| | Before | After | Increase |
|---|---|---|---|
| Synthesis capacity, t/d | 1,800 | 2,700 | 50% |
| Carbamate recycle, kg/h | 41,300 | 95,400 | 130% |
| Specific carbamate recycle, kg/t or urea | 551 | 848 | 54% |
| Water flow recycle, kg/h | 12,900 | 21,100 | 63% |
| Specific water flow recycle, kg/t of urea | 172 | 188 | 9.3% |

## Case 3

This case refers to a total recycle urea plant with an original capacity of 1,000 t/d that was running at an overall capacity of 1,300 t/d. The client asked Casale to integrate the existing urea plant with a 60,000 t/a melamine plant designed with Eurotecnica technology (see Fig. 8). The integration with this type of melamine unit leads to an increase of urea synthesis capacity of about 25% and of water recycled to the loop of about 62% compared to the figures of a stand-alone plant.

For a total recycle plant the impact of the increased water recycle will directly






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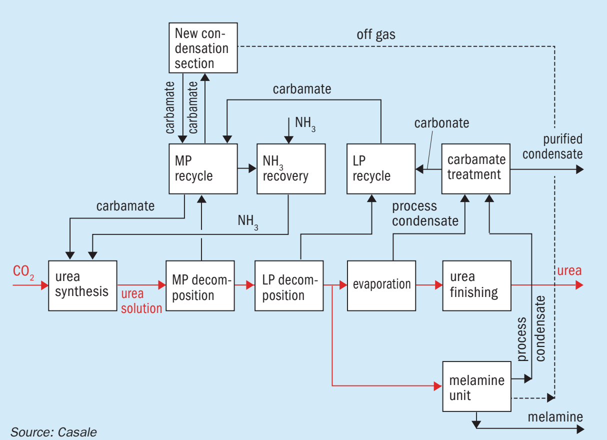
Fig 8: **Urea total recycle plant integrated with Eurotecnica melamine**




*Source: Casale*

Table 4: **Basic figures before and after melamine integration**

| | Before | After | Increase |
|---|---|---|---|
| Synthesis capacity, t/d | 1,300 | 1,680 | 30% |
| Carbamate recycle, kg/h | 67,000 | 105,000 | 55% |
| Specific carbamate recycle, kg/t of urea | 1,237 | 1,509 | 22% |
| $NH_3/CO_2$ loop ratio | 3.48 | 3.58 | - |
| $H_2O/CO_2$ loop ratio | 0.57 | 0.93 | - |
| Synthesis loop conversion, % | 64 | 72 | 12% |

affect the condition of the reactor. In fact in this kind of plant the carbamate recycle is directly fed to the reactor thus affecting directly the $H_2O/CO_2$ ratio into the reactor.

Analysing the parameters of the project it has to be noted that the existing synthesis loop of the urea unit is basically constituted only by the reactor which was designed for a stand-alone plant of 1,000 t/d. After melamine integration it would be running at 1,680 t/d with increased carbamate flow. It was therefore clear that the reactor efficiency would decrease significantly due to the reduced residence time and the increased water content. The reduction in reactor efficiency would have had a negative impact on the downstream medium and low pressure recycling sections that are heavily overloaded.

Apart from the process aspect of providing additional surfaces as well as pumping capacities, the main constraints of the project were the limited space and the reduced shutdown time available to implement the new installations.

Casale therefore decided to adopt a different approach aimed at improving the synthesis efficiency up to a level where the downstream section would not be significantly affected by the integration with the melamine plant. In addition, the new melamine off-gas condensation unit was added with the objective of maximising the utilisation of the water already present in the process.

In order to improve the synthesis loop efficiency Casale adopted its High Efficiency Combined (HEC) technology introducing a secondary reactor, with the relevant stripper used as reboiler and working the existing primary reactor with once through configuration together with the new carbamate condenser. The modification results in a higher conversion of the loop even with the unfavourable $H_2O/CO_2$ ratio. In fact the loop of the stand-alone plant was running with 0.57 $H_2O/CO_2$ ratio and a conversion of 64% while with melamine integration the $H_2O/CO_2$ ratio has increased to 0.93, but thanks to the installation of HEC the conversion of the loop has increased to 70%.

As a result of this modification the medium and low pressure sections do not require significant modifications and the addition of a new HP section can be easily and quickly tied in, thus minimising the required shutdown period.

Table 4 compares some basic figures for the plants before and after melamine integration.

As is clear from the table, the introduction of HEC Casale technology enables the capacity of the HP loop to be increased, thanks to the improvement of the synthesis efficiency. In addition, the specific carbamate recycle flow has increased by only 22% despite a 55% increase in the carbamate flow. The main modifications are those relevant to the synthesis loop:

- new secondary reactor equipped with high efficiency trays;
- new stripper;
- new carbamate condenser;
- new carbamate pumps (replacement of existing).

In addition, to the modifications listed, a new off-gas condensation section was added consisting of LP carbamate pumps and off-gas condenser with relevant tempered cooling water system.

Besides the melamine integration the project also entailed replacement of the crystallisation section with an evaporation section and the provision of a brand new waste-water section.

## Integration of Topsoe technologies at Shchekinoazot

JSC Shchekinoazot is one of the oldest methanol producers in Russia and has been producing methanol since 1966. In 2007, Shchekinoazot started a co-operation with Topsoe that has endured resulting in the optimal integration of Topsoe's ammonia, methanol and hydrogen technologies at Shchekinoazot.

Shchekinoazot is one of the most rapidly developing Russian companies within the chemical industry. The major chemicals produced in the plant are methanol, caprolactam, UFC-85, and AF. In addition, small quantities of ammonia, sulphuric acid, ammonium sulphate as well as carbonic acid are also produced.





The first methanol plant was commissioned by Shchekinoazot in 1966 and had been in operation for 45 years, making it the oldest Russian methanol plant before it was substituted by a new modern M-450 Topsoe-designed plant in October 2011. Over the years the chemical complex has been continuously updated and modernised. Today, Shchekinoazot has modern integrated facilities for production of AF/UFC-85, hydrogen, and oxidation of cyclohexane. Integrating the units and finding synergies between the various plants to ensure optimal performance have always been of the utmost importance to the Shchekinoazot management.

### 450,000 t/a methanol plant

In order to improve the performance of the complex, a decision was taken back in 2007 to construct a new energy-efficient methanol plant with a capacity of 450,000 t/a. Topsoe's two-step reforming technology was chosen for the front-end because Shchekinoazot had free oxygen available at the existing site at a capacity sufficient to feed an oxygen-fired secondary reformer for the above-mentioned plant capacity. By utilising the spare capacity of oxygen in the existing complex, investment cost could be saved and thereby make the project very attractive.

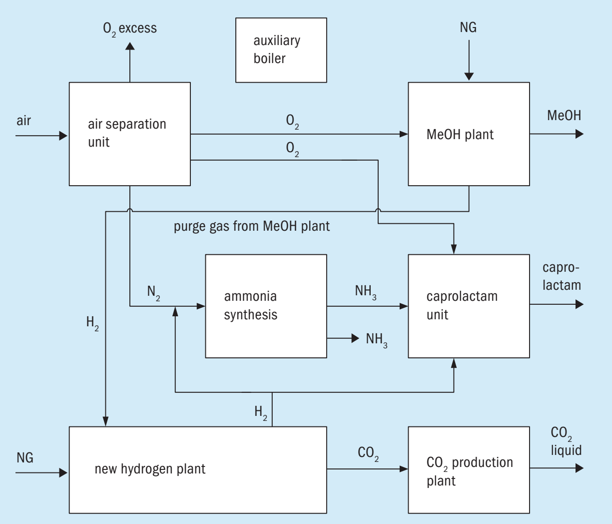
By the end of August 2011, the plant was mechanically complete, all reactors were loaded with Topsoe catalysts, and the protocol of mechanical completion was signed on September 6, 2011. The Topsoe team participated as supervisor in the precommisioning and commissioning of the plant. Natural gas was first supplied to the site on September 20, 2011 and the first methanol was produced on October 9, 2011. The production rate, energy consumption, and quality of methanol were fully in compliance with the guaranteed figures. The overall investment cost amounted to €165,000,000.

Since October 2011, the methanol plant has generally been operated at 100–104% capacity, which increased in 2014 to 106% capacity.

### 26,000 Nm³/h hydrogen plant

Initially, Shchekinoazot produced hydrogen in the front-end section of its small ammonia plant by steam-oxygen conversion of natural gas followed by CO shift. This process unit was commissioned in 1966 and was further partially revamped in 1996. Hydrogen is used for hydrogenation of benzene, which is one of the key steps of

Fig 9: **ShchekinoAzot – integration of process units**




*Source: Haldor Topsoe*

caprolactam production. Along with hydrogen, $CO_2$ was also produced in the old hydrogen production unit, which after additional purification was sold to the food industry as liquid carbonic acid. A programme to modernise the caprolactam production, aimed at decreasing the caprolactam operation costs, required the construction of a new, modern, and efficient hydrogen plant, as the cost of hydrogen production contributes considerably to the overall production cost of caprolactam. Shchekinoazot evaluated that the overall hydrogen consumption for the complex would be approximately 30,000 Nm³/h for both the ammonia and the caprolactam plant. In view of this requirement, Topsoe suggested the Topsoe convection reformer for hydrogen production in order to feed both the caprolactam and ammonia process units while preserving the $CO_2$ production.

The Haldor Topsoe convection reformer (HTCR) is based on the convection principle, which allows for the design of very compact and efficient reformers. This HTCR concept is industrially proven and is operating successfully in a number of hydrogen plants worldwide.

HTCR is the optimal choice for incremental hydrogen requirements in the range of 5,000-30,000 Nm³/h of hydrogen and, depending on the configuration, even higher capacities can be achieved.

The HTCR reactor consists of a vertical, refractory-lined vessel, which contains the tube bundle with several bayonet tubes. Each bayonet tube is surrounded by a flue gas guiding tube, and the heat flux is adjusted by a proprietary flue gas control device. Under the vertical section is a horizontal combustion chamber containing the burner.

The HTCR process comprises the following four process steps:

- desulphurisation of feedstock;
- prereforming;
- convective reforming in an HTCR reactor;
- shift conversion;
- purification by pressure swing adsorption (PSA).

A main characteristic of the HTCR is that it absorbs about 80% of the heat release from the burner into the process. This compares to approximately 50% in a traditionally fired tubular reformer with radiant heat transfer. The main fuel for the burner is PSA off-gas and it is possible to balance the steam generation in the process, which results in a plant without export of steam. This fact determines low feedstock consumption in the plant.



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An HTCR plant is designed for automatic operation between 30 and 100% of the rated capacity and is characterised by a very fast load response. The start-up, normal operation, and shutdown are carried out by a PLC. Industrial experience has demonstrated that the process is very easy to operate, and the requirements for supervision and maintenance are minimal.

## Tailoring the hydrogen plant

When choosing the capacity of the reformer section for the hydrogen plant and also being very well aware of the design concept of the methanol plant, Topsoe realised that purge gas from the methanol synthesis loop of the methanol plant M-450 could be efficiently used as a hydrogen containing source instead of firing in the burners of the primary reformer. This could allow considerable saving of the required reforming capacity in the hydrogen plant and also decrease hydrogen production cost. After a study, which also involved possible integration with neighboring units, the following concept was agreed upon: The overall complex requirement for hydrogen was established to be 26,000 Nm³/h. A new hydrogen plant with a capacity of 15,000 Nm³/h should be sufficient to cover the hydrogen requirement, taking into account 11,000 Nm³/h of hydrogen being added from the methanol plant purge gas. The $CO_2$ removal section and PSA unit were designed to cover the overall hydrogen production of 26,000 Nm³/h. The new BASF OASE® $CO_2$ removal section based on MDEA was supplied, comprising only absorber and flash regenerator without stripper. This concept allowed a saving in investment cost for the new MDEA unit by 40% and also allowed operating the unit without steam import. The $CO_2$ unit was designed to cover the complex demand of approximately 6,000 Nm³/h of $CO_2$. Fig. 9 shows the plant integration.

The contract for the hydrogen plant was signed on June 30, 2010. The Topsoe scope included license and basic engineering and supply of skid-mounted equipment within process battery limits. Topsoe also supplied all catalysts for the plant. The stage project and design outside Topsoe battery limits was made by JSC NIIK.

The plant has been in operation for two years, since December 2012, and has demonstrated stable operation with a high on-stream factor. It has been permanently operated with a load of 100–110%, and its load depends only on Shchekinoazot's actual demand for hydrogen.

## New methanol plant with integrated ammonia production

In 2013, Shchekinoazot decided to construct another new methanol plant and the first idea was to make a repeat of the previous plant. However, Topsoe suggested using a new approach allowing combining methanol and ammonia production. This idea originated from Topsoe's knowledge of Shchekinoazot's site and existing process units, where Shchekinoazot is operating its small ammonia plant at a very high pressure, close to 500 bar, definitely consuming a lot of energy. Therefore, it seemed logical to include a small ammonia production unit in the new methanol plant at a marginal cost and at the same time improve the energy efficiency of the entire complex.

## Topsoe integrated methanol-ammonia process (IMAP™)

For many years Topsoe worked on integrating ammonia and methanol plants to come up with a simple and efficient process layout, which combined the two processes. As a result, Topsoe invented new designs for ammonia-methanol co-production plants. An example of such a plant is the plant designed for Petronas, which has been in operation since 1999 in Malaysia (1,125 t/d of ammonia with coproduction of 200 t/d of methanol or 1,350 t/d of ammonia only). Another plant has recently been commissioned in Russia, Tartarstan for 1,400 t/d of ammonia with co-production of 680 t/d of methanol or 2,050 t/d of ammonia only (see p. 56). In both these projects ammonia is the main product. However, Shchekinoazot required methanol as the main product, and Topsoe suggested the IMAP™ process for this purpose.

The idea of the new IMAP™ design is to keep the most simple process layout in order to minimise investment cost, and in this scheme the product split between ammonia and methanol is given purely by the feedstock composition.

As in the conventional process scheme, a natural gas desulphurisation section is required upstream of the reforming section. In the reforming section, a prereformer is installed. The prereformer can in this case provide approximately 10% higher reforming capacity and reduce the steam production correspondingly.

Topsoe's prereformer technology is well-proven in many hydrogen plants as well as in methanol plants worldwide.

Within the simple design (see Fig. 10) and without applying an air separation unit, the reforming section is designed to produce synthesis gas having a near optimal composition for methanol synthesis. The steam-to-carbon ratio is only 2.2, which is low compared to a normal ammonia plant. The primary reformer outlet temperature is similar to the one in hydrogen plants.

The amount of process air added is given by the required ammonia capacity, aiming at the stoichiometric ratio of hydrogen and nitrogen equal to three at the inlet to the ammonia converter. In this case, the amount of process air relatively to the process gas in the secondary reformer is low, which results in a small temperature increase in the secondary reformer. As such, the methane slip from the reforming section is relatively high.

The $CO_2$ PSA unit is an optional feature, which can be implemented to allow some flexibility in ammonia capacity. In order to increase the amount of excess hydrogen for production of ammonia, a split of approximately 10% of the synthesis gas is fed to a $CO_2$ PSA located at the suction to the synthesis gas compressor. The off-gas from the PSA, which is rich in $CO_2$ and CO, is used as fuel gas to the reformer, and the hydrogen-rich product gas is mixed with the balance synthesis gas. However, the optional PSA unit is not installed in the Shchekinoazot plant.

The methanol synthesis is located at the discharge side of the synthesis gas compressor and is operated at approximately 125 bar g.

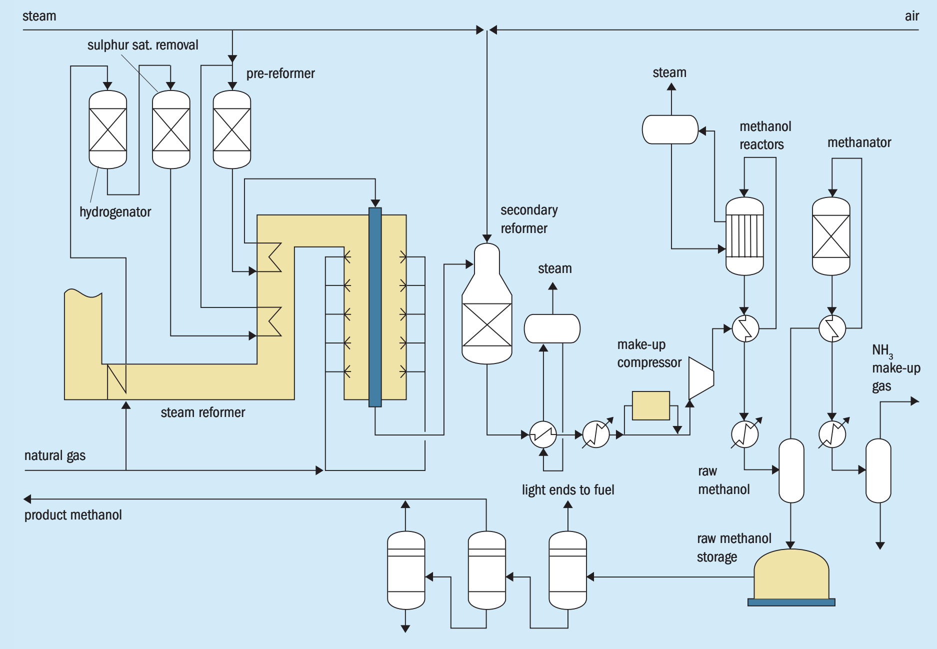
Due to the fact that the IMAP™ plant has methanol as the main product and co-produces ammonia, it is required to have two boiling water reactors followed by one adiabatic reactor to ensure a high conversion in the methanol synthesis. Cooling and separation between all the reactor stages are provided, and the high conversion is desired in order to enable an acceptable $CO/CO_2$ slip and to avoid unnecessary loss of hydrogen in the methanation reactor.

The make-up gas to the ammonia synthesis will typically contain a much higher content of inerts compared to a normal ammonia plant. However, the process layout of the ammonia synthesis loop for the IMAP™ process is similar to a standard





Fig 10: **The IMAP™ process**




*Source: Haldor Topsoe*

ammonia loop. The ammonia converter is the Topsoe S-300 converter, which is a 3-bed radial flow converter.

Since there is no compression stage between the methanol synthesis and ammonia synthesis, the two synthesis units are operated at similar pressure levels. The pressure is approximately 125 bar, which is a compromise for the methanol synthesis and the ammonia synthesis loops.

In the majority of existing ammonia plants, the recirculation compressor is located in the same compressor casing as the last stage of the synthesis gas compressor, thereby running on the same shaft and running at the same speed as the make-up gas compressor stages. This has proven reliable and safe in operation.

However, for flexibility during start-up of an IMAP™ plant, the recirculation compressor for the ammonia loop is a separate compressor with its own driver.

The IMAP™ design allows a simplified scheme for co-production of methanol and ammonia, which results in a low investment cost. Savings in capex/opex are due to the fact that there is no need for a $CO_2$ removal section and CO shift section, which are typical units in a conventional ammonia plant. Moreover, there is no need for an ASU, which is a high cost utility section of a methanol plant based on a two-stage reforming or autothermal reforming process. Methanol and ammonia syntheses are performed at a similar pressure, which means installation of a common compressor for the once-through methanol synthesis section and the downstream ammonia synthesis section.

The IMAP™ plant is self-sufficient without import or export of steam and electricity. The specific energy consumption is low even though the focus has been on savings in investment cost. The plant features a specific energy consumption of 7.10 Gcal/t of combined product.

A contract was signed between Shchekinoazot and Topsoe at the end of September 2013, covering the basic engineering of an IMAP™ plant with methanol capacity of 1,350 t/d and ammonia capacity of 415 t/d. The new methanol-ammonia plant will be located at the site of the old methanol plant, which has already been dismantled. The commissioning of the new IMAP™ plant, M-450/A-135, is scheduled for 2018. ■

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# Boosting ammonia capacity

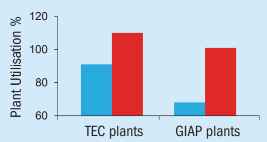
Increased ammonia capacity in Russia and the CIS is being used to monetise natural gas into valuable fertilizer products. This article describes some of the revamping technologies and catalysts being used to modernise aging ammonia plants in the region for increased efficiency and higher production capacities and reports on the first large scale fertilizer complex to start up since the dissolution of the Soviet Union in 1991.

The large-capacity ammonia production plants in Russia and the CIS were mainly constructed in the 1970/80s. These production processes were largely based on the technology of Toyo Engineering Co. (TEC) or that of the Russian Institute of Nitrogen Industry (GIAP). The GIAP plants and the TEC plants typically had an original design capacity of 1,360 t/d ammonia.

Much of the current capacity is aimed at supplying export markets, which are subject to international competitive pressures. Within Russia over the last 25+ years, due to increasing feedstock prices and an increase in shareholder requirements for profits, plant operators have faced the dual challenge of being more efficient whilst increasing production so that they can remain effective in supplying global fertilizer markets.

Data from GIAP nitrogen industry reports in Fig. 1 shows how plant utilisation has improved dramatically over the last 25+ years. The most dramatic increases in utilisation have been achieved more recently with leading plants in the region now operating at >135% utilisation rate.

Fig 1: **Nitrogen industry improved plants utilisation**




*Source: Johnson Matthey*

## Technological differences

Many of the large capacity ammonia plants in Russia and the CIS are 30-40 years old and have some distinctive design features.

The reforming furnaces in both the GIAP and TEC plants have larger radiant boxes than is usual in ammonia plants built outside the CIS during the same time period, with over 500 catalyst tubes.

The $CO_2$ removal sections in these plants are also notably different from those of standard 'western' ammonia plants of the day. TEC plants are usually (but not always) equipped with two absorbers and two strippers (regenerators). In contrast, the $CO_2$ removal units in the earlier (AM70) GIAP plants were originally designed with one absorber and one regenerator, but the absorber is of rather complex internal design, being equipped with trays interconnected by several cylindrical downcomers.

The revised $CO_2$ removal process used in later (AM76) GIAP plants is equipped with one absorber (similar to that of the AM70 process) and two regenerators. The top part of each regenerator is equipped with 20 trays between which are two solution/solution heat exchangers, making a total of 38 exchanger bundles in each column.

The synthesis compressors in both TEC and GIAP plants were designed with four compression stages to supply a maximum synloop operating pressure close to 300 kg/cm$^2$g. The turbocompressor units installed in these plants were typically designed for a capacity of 1,360 t/d and were built by machinery companies such as Mitsubishi Heavy Industries, Dresser-Rand, Hitachi, Fuji, and Nuovo Pignone in TEC plants and by Nevsky and Kazansky in GIAP plants.

Fig 2: **Ammonia absorption refrigeration system**

PHOTO: CASALE

Interstage cooling was provided by air coolers while, in most plants, there was a water removal device (ammonia washing unit or molecular sieve dryer) between the second and third compressor case.

The synthesis loop in the GIAP plants is usually equipped with a single ammonia converter, while in the cold section of these plants a cold gas/gas exchanger is integrated with the high-pressure loop separator. The TEC plants were originally designed with a single ammonia converter, but most have since been revamped by adding a parallel supplementary converter.

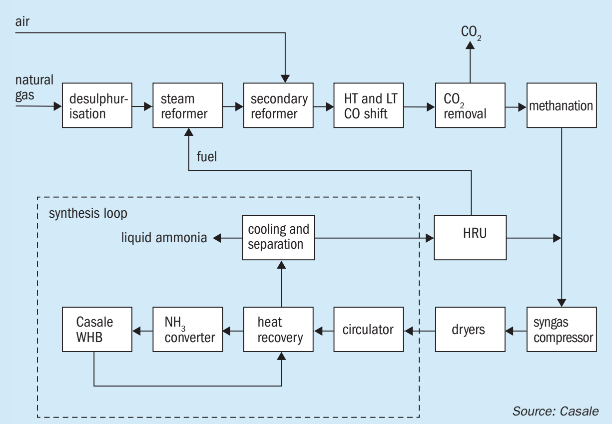
Another big difference between GIAP plants and most western ammonia plants is the use of absorption refrigeration (Fig. 2) instead of the more usual compression refrigeration system. The GIAP plants are designed with several of these ammonia absorption units.







Fig 3: **Typical ammonia plant block scheme for a Russian type plant**




*Source: Casale*

## Turbocompressor modernisation

In recent years it has become desirable to expand Russia's aging 1,360 t/d ammonia plants to a target capacity of 1,700-1950 t/d. Such an increase in capacity is far beyond the design capability of the original turbocompressors: an increment of this size cannot be accommodated merely by running them faster because their efficiency drops off on account of aerodynamic effects and the risk of damage reduces their reliability. In any case, their drive turbines do not meet modern-day standards for energy-efficiency (steam consumption).

To replace these compressors with new ones would be prohibitively expensive, so there has been a trend to modernise the flow parts of the existing machines.

In 2011, Entechmach RPC LLC, a Russian company specialising in the upgrading of turbo-compressor equipment, and the Polish company ALSTOM Power started a joint development project for the modernisation of compressors and turbines to meet the requirements of ammonia producers for 1950 t/d of ammonia – the "Ammonia 1950" project. The project was implemented in 2014.

Such a huge hike in production (more than 35% above the original design value) demands careful study of the changes which need to be made both in the process and in the compressor and turbine. The task of determining just how to accomplish it was carried out by design organisations such as Casale, who carried out the analysis of the complete process plant in co-operation with the plant operators, whose long-term experience of operating the process and its machinery is invaluable in defining the exact combination of changes in the equipment and in the process conditions that will make it possible to achieve the objectives of the revamp.

The Ammonia 1950 project is based on several main requirements for the dynamic equipment, namely:

- to adjust the characteristics of the air compressors to attain the target capacity;
- to obtain from the turbine drive the requisite power and speed matching the optimal requirements of the compressor for the minimum steam consumption;
- to ensure continuous uninterrupted and smooth operation within the safety margins specified in the API 612 and API 617 standards;
- to increase the efficiency of compressor and its turbine and thereby reduce the specific energy consumption in the ammonia production.

## Casale revamping projects

In recent years Casale has used its know-how, technologies and experience developed in complete plant revamps in other parts of the world to develop tailor-made revamping schemes for the rather complicated GIAP and TEC plants in Russia and the CIS.

Superficially, the flow scheme of these plants (Fig. 3) appears very similar to that of ammonia plants more or less anywhere in the world. Only after each single area has been deeply analysed do some fairly significant differences between the Russian-type ammonia plants and their western counterparts become evident.

The first step in analysing a plant for a revamping project is to idenify the bottlenecks, i.e. the capacity-limiting items of the plant. There are various reasons why these items might be operating at their maximum load, for example, they may be worn out and no longer able to operate at their original efficiency, or their technology may be obsolete, or they may have been underdesigned in the first place.

However, in some cases an apparent bottleneck in an equipment item may be alleviated by making modifications elsewhere in the plant to change its inlet or outlet conditions sufficiently to allow that item to operate more efficiently. A good example of that is the additional capacity that can be created in the ammonia refrigeration section when modifications are made elsewhere in the ammonia synthesis loop.

Ammonia Casale has demonstrated this in several successful revamping projects that it has undertaken in Russia and the CIS, mainly on GIAP, TEC and Chemico plants. In most of them extra capacity in the refrigeration section was created by installing a new cartridge in the ammonia converter with three axial-radial flow catalyst beds (Fig. 4) in place of the axial-flow internals originally provided. Thanks to the significantly greater efficiency of the Casale internals and their lower pressure drop, both the operating pressure and the gas circulation rate could be reduced (see Table 1). That, in turn, lowered the duty on the synthesis loop chillers to the extent that a small to moderate capacity increase was possible without modifying the refrigerant compressor in the TEC and Chemico plants or the ammonia absorption refrigeration units, the so called "AXY" units, in the GIAP plant.

Besides ammonia converter internals, Casale has supplied the Russian/CIS countries with other proprietary technologies such as Casale's secondary reformer burner, ammonia washing unit and shift converter internals, and has undertaken the engineering work to upgrade reforming and $CO_2$ removal sections. Most of these modifications were done on an individual basis rather than as part of a complete plant revamp.





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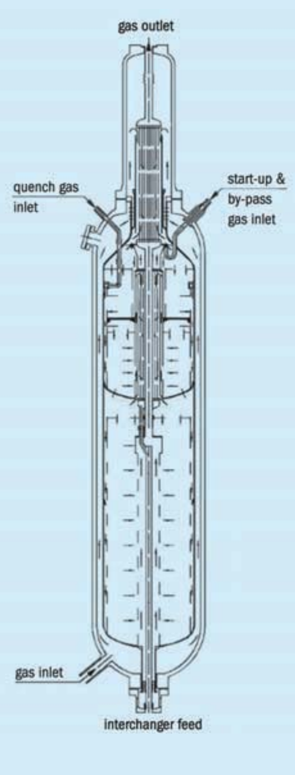
Fig 4: **Revamped ammonia converter**



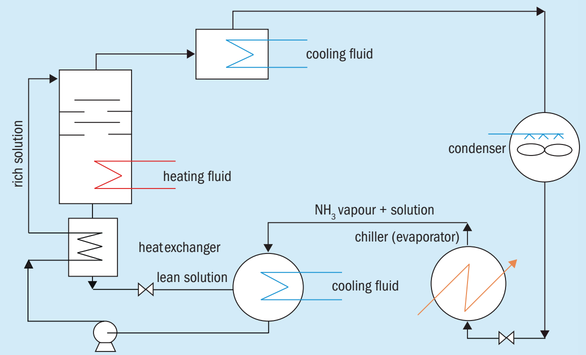

*Source: Casale*

Table 1: **Synloop main operating data after ammonia converter revamping**

| | Production (t/d) | $NH_3$ at converter outlet (mol-%) | Circulation ($Nm^3/h$) | Pressure at converter inlet ($kg/cm^2g$) |
|---|---|---|---|---|
| Existing converter | 1308 | 14.40 | 714,000 | 282 |
| Casale revamp | 1381 | 18.30 | 585,000 | 241 |

*Source: Casale*

Fig 5: **Ammonia absorption refrigeration system**




*Source: Casale*

## New ammonia absorption refrigeration unit for GIAP AM70 plant

GIAP ammonia plants are different from all the other ammonia plant types in the world in that they use ammonia absorption refrigeration (Fig. 5) to provide the chilling needed to condense the ammonia produced. As they are such a rarity not much effort has been made in the past to make improvements to these units.

Ammonia absorption refrigeration systems have, in fact, been in use for more than 70 years. They are sealed systems and are known to be very reliable; they are virtually maintenance-free. The only moving parts in the circuit are a number of pumps. The instrumentation is simple and the control of the plant can be highly automated. The power consumption of an absorption refrigeration unit is very low, but it does require a source of low-grade heat. This heat can be supplied either as low-grade steam, from a gas burner, or any from other source of heat that might be available.

The popularity of absorption refrigeration waned in the face of the development of more reliable ammonia compressors, which made it possible to design and supply a refrigeration circuit at much lower cost. The disadvantage of compression-based refrigeration systems, however, is that high-grade power or steam is required to drive the compressor.

Over the last decade the structure of the compressor market has changed. Larger compressor manufacturers have swallowed up the smaller manufacturers, thereby significantly reducing competition. The drive for ever larger compressors, in particular for LNG plants, has resulted in the principal suppliers concentrating their attention ever more on the larger end of the market, and this has led to a marked increase in prices at the less interesting smaller end of the market. There is also evidence that western vessel manufacturers may now be employing more advanced manufacturing technologies to remain ahead of or at least competitive with Chinese prices. All these factors have made ammonia absorption refrigeration competitive once more as a means of recovering product from the ammonia synthesis loop.

The GIAP AM 70 ammonia plant is designed with three types of ammonia absorption unit, capable of supplying ammonia at +1°C, at -10°C and at -30°C. The most critical ammonia absorption unit is the one that supplies ammonia to the synthesis loop chillers. These chillers work with ammonia at -10°C and, especially during summer, are not able to guarantee the same performances as during the cold season. The main reason for this underperformance is the use of air coolers as the rectifier cooling unit in the existing ammonia absorption unit.

With the aid of a selected ammonia absorption refrigeration system designer, Casale has designed a package which is





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able to supply ammonia at -10°C, in which the rectifier cooling unit is an evaporative condenser. Casale engineered the integration of this new unit in the existing ammonia absorption refrigeration units. All the project steps, from basic engineering up to construction, were controlled by Casale. The new AXY was the biggest ever supplied and installed in Russia (~10 Gcal/h).

## Casale revamp of a TEC ammonia plant

Casale has carried out a comprehensive revamp of a TEC ammonia plant in Russia. The plant is located in the south of Russia and was built in the early 1970s with a nameplate capacity of 1,360 t/d. In the late 1980s the plant was revamped by TEC up to a targeted capacity of 1,700 t/d.

Others minor modifications were subsequently made to the plant, however the capacity achievable by the plant was 1,680 t/d during the winter season and only 1,600-1,650 t/d during summer, due to process air compression and plant cooling capacity limitations.

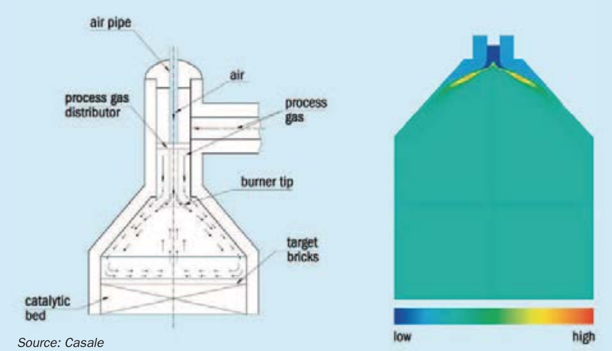
Casale started the revamping conceptual study in 2010, and several alternatives were developed based on different plant revamping configurations.

The client selected one of these configurations and later Casale was appointed to develop the basic, detail engineering procurement of the majority of equipment, bulk material and to the supervision of construction and commissioning activities. Casale could be considered as the EP contractor for the project. In addition, Casale was responsible for adaptation of the engineering to Russian standards. This activity was performed through a Russian engineering institute.

Casale provided an experienced and structured project organisation to manage and execute the revamping project. In particular, considering that the documentation was not completely updated, to expedite the plant analysis and the subsequent steps of the project, Casale utilised plant laser scanning. This tool provides a precise picture of the plant layout and allows an extremely accurate three-dimensional model of the plant to be worked up.

Using "point clouds" from the laser scan, it is possible to study specific sections of the 3D colour model to check the safety, accessibility, maintainability and constructability of proposed modifications in minute detail. This safeguards against

Fig 6: **Casale advanced design burner and gas distribution**




*Source: Casale*

problematic interference between new and existing parts of the plant. Thus the technique drastically limits the likelihood of mistakes resulting in unforeseen problems that commonly affect revamping projects, and it makes it much easier to control the schedule and cost of the project.

## Execution of the plant modification

Most of the new equipment and the material required for the modification of some specific existing equipment (e.g. secondary reformer, ammonia converters, HTS) were supplied by Casale together with the bulk material.

The plant modification/construction was performed by the client while Casale operated as advisor, with the exception of the proprietary items which were installed by Casale.

The Ukrainian crisis created problems for the material delivery, however the plant was shut down as per schedule at the end of September 2014 and the turnaround was completed as per schedule at the middle of November of the same year.

The major changes were:

- revamp of the primary reformer radiant box (activity performed in 2011);
- replacement of the secondary reformer burner;
- revamp of the HTS internals;
- upgrading of the $CO_2$ removal section;
- revamp of the air compressor;
- revamp of the synthesis gas compressor;
- revamp of the parallel smaller ammonia converter;
- installation of a chilled water circuit;
- installation of an additional BFW pump;
- replacement of the turbine drives for the primary reformer ID fans;
- installation or replacement of some heat exchangers;
- revamping of air compressor;
- replacement of the air compressor turbine;
- replacement of the steam condenser of the air compressor turbine;
- replacement of sections of the steam condenser of the syngas and natural gas compressors.

## Primary reformer and secondary reformer

The primary reformer radiant box is designed with more than 500 catalytic tubes with an internal diameter of 85 mm. Since the existing tubes were already at the end of life, the primary reformer revamp was accomplished by retubing with thinner-walled microalloy tubes of the same outside diameter (115 mm), inner diameter of tubes was increased to 92 mm. The new tubes guaranteed a heat flux within the specification for this section.

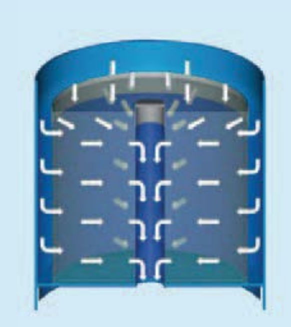
Flue gas is withdrawn from the primary reformer by two parallel ID fans. As the existing back-pressure turbine drives of these fans were already operating at their maximum capability, they were replaced with new ones.

The secondary reformer burner was replaced by a Casale advanced secondary reformer burner. The new burner imposes lower pressure drop than the original one on both air and gas sides. It also produces a shorter flame, which prevents flame impingement on the surface of the catalyst bed, and more even process gas distribution, which allows a closer approach to the



AMMONIA IN RUSSIA

Fig 7: **Axial-radial concept**



*Source: Casale*

equilibrium. That in turn means better use of catalyst bed with the methane slip reduction and, consequently, the inerts content in the synthesis make up gas is lower.

Adoption of the Casale secondary reformer burner (Fig. 6) allowed the secondary reformer pressure drop to be reduced from 1.14 kg/cm² to 1.0 kg/cm² despite the increase in plant load from 1,680 t/d to >1,980 t/d.

## HTS internals

To guarantee a reduction in the operating pressure drop across the HTS converter, the axial-flow internals were replaced with the Casale axial-radial type (Fig 7).

In an axial-radial catalyst bed most (~90%) of the gas passes through the catalyst bed in a radial direction, resulting in much lower pressure drop than in a purely axial-flow catalyst bed. Not only is the pressure drop lower to start with, it rises significantly less as the catalyst ages. That means that the suction pressure at the synthesis gas compressor is always higher than in the unmodified plant and so the syngas compression energy is reduced. Mechanically the bed is very simple, comprising just two vertical perforated walls and one closure plate. The vessel was loaded with Clariant Shiftmax 120 catalyst with a tablet size of 6 x 6 mm.

Adoption of the axial-radial internals allowed a significant energy saving and reduced the pressure drop from 0.8 to 0.47 kg/cm² while allowing for the front end load increase to >19,80 t/d.

## $CO_2$ removal section

One of the targets of the revamp was to reduce the steam:carbon ratio substantially, from 3.8 down to 3.0-3.1. To reach this target it was necessary to reduce the $CO_2$ removal section heat demand in order to keep the $CO_2$ slip below 500 ppm mol. This was achieved by adapting the $CO_2$ removal system to the GV Low-Energy scheme.

The $CO_2$ removal unit in the TEC plant was originally designed with two absorbers and two regenerators. The only hardware modifications needed in this section were to reroute some pipework and install a process ejector to allow the two regenerators to run at different pressures in series instead of in parallel. The final outcome of this modification was to increase the number of vapour/liquid equilibrium stages, and to exploit the solution flash between the two regenerators, which had the effect of reducing the regeneration heat requirement and, thus, steam consumption in the reboilers.

Immediately after start-up the plant experienced problems in achieving the targeted production due to foaming phenomena in the absorber due to dirt and the presence of oil.

To overcome this issue it was decided to add some antifoam agent and to perform a more accurate cleaning of the system keeping a continuous flow through the $CO_2$ removal section filters. Finally the foaming phenomeon was significantly smoothed allowing the plant to achieve the targeted performance.

Table 2: **Plant performance before and after revamp**

| | Pre-revamp | Guarantees | Post revamp |
|---|---|---|---|
| Production, t/d | 1650 | 1950 | ~1980 |
| Energy saving, Gcal/tT | | 0.62 | 1.02 |
| Specific energy consumption, Gcal/t | 9.12 | 8.5 | 8.1* |

*(*) Calculated value according to the DCS print out screen.*

*Source: Casale*

## Machinery

The air compressor was one of the main bottlenecks of the plant and, therefore, a complete revamp of the machine, including its steam turbine drive, was required to make the plant suitable for the increased plant load.

The synthesis gas compressor train was theoretically adequate for the new operating conditions with the exception of the circulator wheel. However, in order to optimise the operation of this machine and reduce its energy consumption under the new conditions it was decided, jointly with the client, to revamp this compression train as well.

Under the new conditions the existing BFW pumps would be working too close to their rated conditions and, considering their age and that of their turbine drives, it was decided to install a smaller, electrically driven BFW pump in parallel with the existing ones.

## 'Baby' synthesis converter revamping

The original TEC plant synthesis loop was revamped several years ago through the installation of an additional ammonia converter in parallel with the original one.

This additional converter is smaller (it is known as a 'baby' converter) than the original one and is based on three axial beds with quench cooling.

In view of the fact that the main converter was going to be revamped by Casale according to the axial-radial concept, Casale decided to revamp the "baby" converter as well so as to decrease the pressure drop across this revamped reactor and to increase its conversion efficiency.

The selected layout had two beds and an indirect interchanger.

The main converter which had already been revamped by Casale some years ago was refurbished to replace the catalyst bed wire mesh with monolithic slotted plates.

New catalyst was loaded in the main and baby converters. The client selected Clariant Amomax10 based on Wustite type catalyst.

## Chilled water

In spite of the significant load increase, the refrigeration section did not require any modification, thanks to the installation of new chilled water exchangers in the synthesis loop and in the syngas compressor interstage, just upstream of the existing ammonia chillers.



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The chilled water is obtained from a lithium bromide unit, which supplies water at low temperature, using as utilities low-level waste heat (e.g. LP steam) to regenerate the system and cooling water to remove the heat exchanged. This solution prevented the revamping of costly items such as the refrigerant compressor, avoiding an increase in the consumption of valuable energy such as MP steam (35-40 kg/cm²g).

During the plant start-up only the chilled water system was tested because the cooling water and the environmental air temperature were already quite low keeping the load on the refrigerant compressor within its limit, for this reason it was decided to keep this new section out of service.

When the weather gets hotter the chilled water system will be commissioned to maintain the refrigerant compressor within its limits.

## Plant performance

The performance of the plant after start-up is shown in Table 2.

## Johnson Matthey ammonia catalysts

Over the years, Johnson Matthey has been closely involved in the development of existing plants by increasing capacity through the use of better catalyst technology, as well as in providing the first-fill of catalysts and commissioning technical support to new units built within the FSU region.

Many improvements to the 1,360 t/d plants have been facilitated using advances in catalysts and related technologies. Plants have been revamped to improve efficiency and/or increase throughput. With a deep understanding of catalysis and ammonia plant operations, Johnson Matthey has helped contribute engineering, equipment, process models and reliable catalysts that have been used in the successful revamp of Russian plants.

The first catalytic step in the ammonia plant is the purification step. Johnson Matthey's catalyst technology has added value to a number of TEC ammonia plant revamps by making a low-temperature retrofit of the purification section.

The original arrangement of the purification section is shown in Fig. 8. A hydrodesulphurisation (HDS) vessel was followed by a lead-lag zinc-oxide unit operating at high temperature, with the natural gas feed being heated by an upstream pre-heater, after which a hydrogen recycle stream was added from the low-pressure delivery of the syngas compressor.

The objective of the retrofit was to achieve increased heat recovery of the flue gas in the convection zone and to improve the overall plant energy efficiency.

The main stages of the plant retrofit were:

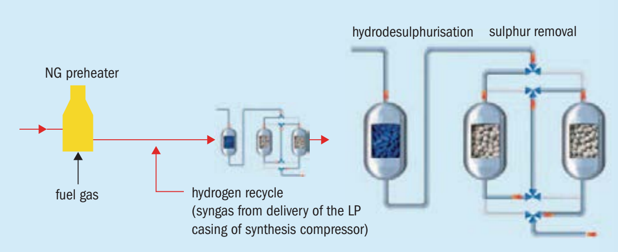
- the installation of two additional coils in the low temperature end of the convection section to improve heat recovery;
- and the conversion of one of the remaining convection coils from boiler feed water heating to natural gas pre-heating.

This made it possible to decommission the fired natural gas pre-heater which helped improve the overall plant efficiency and also removed an item of equipment that represented an additional risk to plant safety and reliability. Across the global ammonia industry, natural gas pre-heaters are known to be prone to incidents with a number of explosions and fires having been documented.

Changing the hydrogen recycle source to ammonia synthesis loop purge (rather than syngas from the exit of the low-pressure synthesis compressor casing) further helped reduce losses, increasing the ammonia make and adding further efficiency improvements.

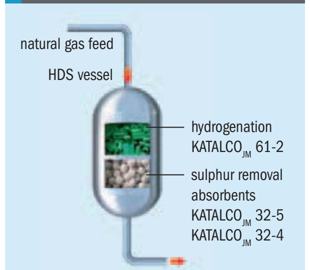
This change to the TEC plant was achieved by using short loads of low-

Fig 8: **Original standard purification flowsheet**



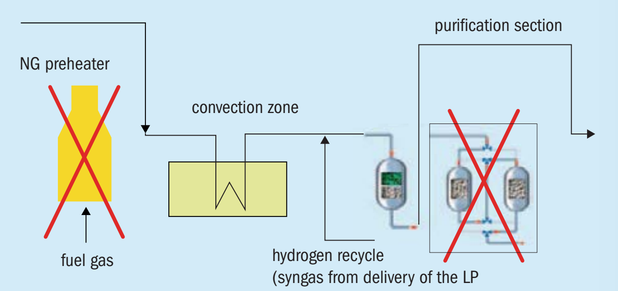

*Source: Johnson Matthey*

Fig 9: **Catalysts and absorbents in one vessel**




*Source: Johnson Matthey*

Fig 10: **Low temperature purification after the retrofit**




*Source: Johnson Matthey*





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Table 3: **Lifetimes achieved with KATALCO$_{JM}$ primary reforming catalysts**

| Plant design | Operating rate, t/d | Reformer type | Catalyst volume, m³ | Lifetime, years |
|---|---|---|---|---|
| GIAP | 1,450 – 1,550 | top-fired | 26 | 16 |
| TEC (Kellogg) | 1,550 – 1,650 | top-fired | 29 | 10 |

*Source: Johnson Matthey*

temperature, high activity HDS catalyst KATALCO$_{JM}$ 61-2 and KATALCO$_{JM}$ 32-5/32-4 zinc oxide absorbent. The catalysts and absorbents were placed in one vessel as shown in Fig. 9.

By using a single vessel it allows the existing lead-lag zinc oxide unit to be bypassed. Bypassing the existing unit helps to shorten start-up time, saves heat, reduces the pressure drop across the front end of the plant and improves the plant efficiency. A schematic of the process after the retrofit is shown in Fig. 10.

Following the retrofit of the TEC plant the plant efficiency was significantly improved, with a 3.8% reduction in natural gas consumption per tonne of ammonia produced. The exit flue gas temperature from the convection zone was reduced from 248 to 175°C due to the improved process heat recovery. The new low temperature desulphurisation system has been well proven, with an operating temperature maintained in the range of 265-300°C at all times. The $H_2S$ level in the natural gas exit the purification system is <0.01 mg/m³.

The operating life of the short-loaded catalyst and absorbent charges to minimise pressure drop exceeded the design expectation, and have been online for eight years.

The top fired primary reformers in the TEC and GIAP designed plants in the Russian market typically have an original capacity of 1,360 t/d. Since the retrofit, the plant now operates typically at 1,850 t/d, representing 136% utilisation.

Johnson Matthey supplied the plant with primary reforming catalyst and its dense catalyst loading service to optimise the performance parameters of pressure drop, minimise methane slip and minimise tube wall temperature (TWT).

Johnson Matthey's KATALCO$_{JM}$ primary reforming catalysts were chosen by the customer for their best combination of activity, pellet size/shape, mechanical properties, heat transfer coefficient and pressure drop. Performance parameters after one year of operation are as expected and the pressure drop is stable. Methane slip is lower than the predicted level. Tube wall temperature inspections have confirmed that there are no hot spots.

Historically, Russian plants have had annual plant shutdown cycles, but the adoption of improved catalyst technologies has led to significantly longer run lengths. Table 3 outlines the lifetimes achieved with KATALCO$_{JM}$ primary reforming catalysts.

Following primary reforming, the secondary reformer is a complex reactor in which the nitrogen is added to the process via a burner above the catalyst bed.

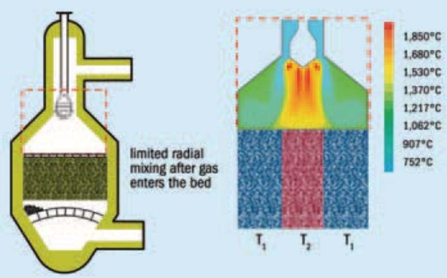
Figure 11 shows an example of a double cone shaped burner originally used in many of the older Russian plants.

Since the early 1990s the use of computational fluid dynamics (CFD) has been used to understand fluid flow problems, including in secondary reformers and in particular the combustion process mixing that takes place after the air from the burner mixes with the process gas above the catalyst bed. With the benefit of CFD, analysis used on the original design clearly shows that there is a hot core of gas at the centre of the bed from an intense flame from the burner. This results in the bed having two distinct temperature zones.

Once the gas has entered the catalyst bed at different temperatures, radial mixing of the gas is limited, so the gas exits at different temperatures, T1 and T2. Due to the shape of the steam:methane equilibrium curve mixtures of hot and cool regions will always give a less favourable equilibrium when compared to a uniform temperature resulting in a higher methane slip and less efficient plant operation.

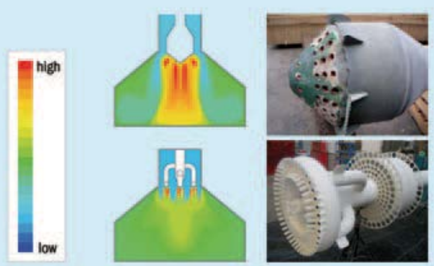
Johnson Matthey has developed an effective technical solution with its KATALCO$_{JM}$ PERFORMANCE ring burner. Figure 12 below shows photographs of a traditional original burner design (top) and a more modern Johnson Matthey ring burner (bottom). A CFD analysis of these designs shows the improvement from the KATALCO$_{JM}$ PERFORMANCE ring burner which gives a significantly improved combustion pattern due to the large number of nozzles giving smaller flames and effective mixing, meaning that the temperature inlet the catalyst bed is lower and has a more even temperature, thereby providing significant benefits in terms of performance and reliability.

Fig 11: **Double cone shaped burner**




*Source: Johnson Matthey*

Fig 12: **Traditional original burner design (top) and modern Johnson Matthey ring burner (bottom)**




*Source: Johnson Matthey*

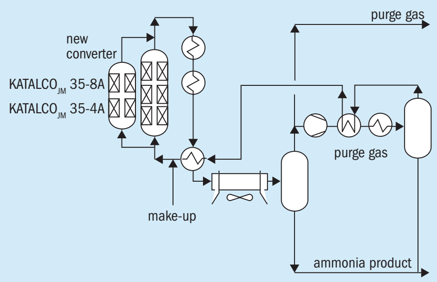




Fig 13: **Top of a HTS catalyst bed grid badly clogged with sodium and phosphate salts from the boiler water.**

PHOTO: JOHNSON MATTHEY

Fig 14: **New ammonia converter in parallel to existing converter.**




*Source: Johnson Matthey*

There are now 15 KATALCO$_{JM}$ PERFORMANCE ring burners in operation in FSU ammonia plants.

As Russian plants have been uprated, more pressure is placed on the waste heat boiler downstream of the secondary reformer. The following case study provides an excellent example of the improvement in reliability that can be offered by modern catalyst technology that has excellent activity and good resistance to boiler leaks.

A 1,360 t/d TEC design plant operating at 1,700 t/d had 80 m³ of KATALCO$_{JM}$ 71-5 high temperature shift (HTS) installed. After four months in operation a leak developed upstream of the waste heat boiler causing the HTS pressure drop to increase. The catalyst ran for three months until the planned shutdown when the HTS bed was skimmed removing 12 m³ catalyst; the plant then restarted with a normal pressure drop.

Nearly a year later a second serious leak developed in the waste heat boiler resulting in the catalyst bed pressure drop increasing towards 1.2 bar. The bed was skimmed again in another planned shutdown. Figure 13 shows a photograph of the top of the HTS catalyst bed grid badly clogged with sodium and phosphate salts from the boiler water.

After the second skim the remaining catalyst bed was only 52 m³ (65% of the original volume). This short load continued in operation for a further two years before being replaced with a fresh charge of KATALCO$_{JM}$ 71-5.

Table 4 provides a summary of the waste heat boiler leaks and the impact of these on the key HTS operating data of the KATALCO$_{JM}$ 71-5 charge.

As previously mentioned, leading plants have been pushing capacity to achieve upgrades that are 35% higher than the original plant capacity. At this level of production it becomes necessary not just to go beyond upgrading the original ammonia synthesis converter by fitting improved internals, but to add additional ammonia synthesis catalyst volume with an additional booster converter.

The next case study concerns a 1,360 t/d plant designed by GIAP that was built in 1977. The plant was already operating at 1,600 t/d and the ammonia converter in the synthesis loop had already been changed to an axial-radial flow pattern. The desire was to increase the plant capacity further to 1,800 t/d.

Following a revamp delivered by ThyssenKrupp Industrial Solution (TKIS), the following changes were made to the loop. A

Table 4: **Components modeled in simulation**

| Date | Inlet, °C | Exit, °C | CO slip, % | DP, bar | Plant rate, t/d |
|---|---|---|---|---|---|
| Competitor catalyst after 4 years of operation, prior to replacement. | | | | | |
| 06/2011 | 358 | 409 | 2.40 | 0.36 | 1,660 |
| 80 m³ of KATALCO$_{JM}$ 71-5 catalyst installed. | | | | | |
| 09/2011 | 323 | 391 | 1.71 | 0.26 | 1,670 |
| After the 1st leak and skim removing 12 m³ catalyst. | | | | | |
| 05/2012 | 326 | 395 | 2.10 | 0.24 | 1,650 |
| After the 2nd leak and second skim removing 16 m³ catalyst. | | | | | |
| 05/2013 | 335 | 401 | 2.16 | 0.26 | 1,730 |
| New charge of KATALCO$_{JM}$ 71-5 catalyst installed – 80 m³ | | | | | |
| 06/2015 | 329 | 394 | 1.76 | 0.36 | 1,660 |

*Source: Johnson Matthey*



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Table 5: **New plants in Russia and Turkmenistan**

| Plant | Country | Process technology | Capacity, t/d |
|---|---|---|---|
| Tejencarbamide | Turkmenistan | TKIS Uhde | 600 |
| Marycarbamide | Turkmenistan | KBR Technology | 1,200 |
| Linde Azot | Russia | Linde Ammonia Concept | 1,350 |

*Source: Johnson Matthey*

new synthesis gas drying unit was installed to remove water from the make-up flow of syngas. This allowed fresh make-up syngas to the loop to be fed directly upstream of the converter, reducing the inlet ammonia concentration and thus increasing the driving force for the reaction and conversion across the converter.

Within the loop, an additional ammonia converter was installed consisting of two radial catalyst beds with two internal heat exchangers. The new converter was placed in parallel to the existing converter to keep the pressure drop low (Fig. 14).

Johnson Matthey catalysts have also been supplied to a number of other new plants in the region that have recently been built or are under construction (see Table 5).

## New grassroots co-production plant in Tatarstan

A new fertilizer complex has been built in the Republic of Tatarstan, Russia and will use natural gas as feedstock. The new Tatarstan fertilizer complex,has been commissioned and reached 100% production at the beginning of September 2015. The complex has a nameplate capacity for 2,050 t/d ammonia, alternatively 1,400 t/d ammonia with the co-production of 680 t/d methanol, 2,050 t/d urea synthesis and granulation, together with associated utility and offsite facilities. Excess ammonia will be exported to an existing ammonium nitrate plant.

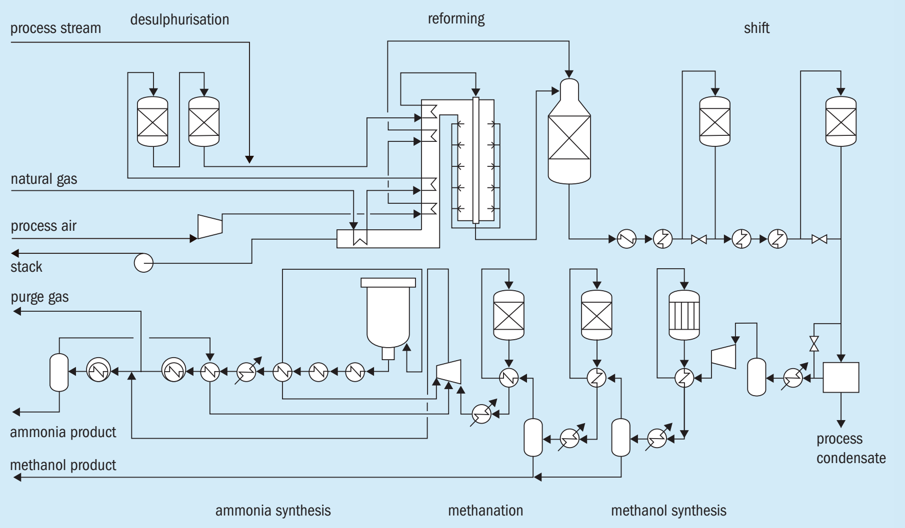
With strong support from the Tatarstan government, the project is a collaboration between the owner Ammonii, the Russian Design Institute NIIK, the engineering and procurement (EP) contractor Mitsubishi Heavy Industries (MHI), and the Chinese construction company CNCEC.

The project is the first large scale fertilizer complex to be built since the break up of the Soviet Union and serves as a benchmark for:

- technology selection, project development starting from the first dialog in 2006 between the owner, technology licensers and EP contractor;
- adaptation to Russian standards, documentation for authority approval and plant costing during the early work phase including the licenser's process design and basic design;
- amicable negotiation of the engineering procurement and construction (EPC) contract;
- project financing;
- overcoming difficult issues during the contract including inland transportation and construction in an extremely low temperature region.

Haldor Topsoe is the licensor for the IMAP™ co-production technology, BASF is the licensor for the $CO_2$ removal section, Saipem is the licensor for the urea melt plant and Uhde Fertilizer Technology is the licensor for the urea granulation plant.

Fig 15: **Process layout of Tatarstan ammonia-methanol co-production plant**




*Source: MHI/Topsoe*

## Process layout

The selected process scheme was arrived at in close collaboration with the plant owner, Amonii. It is a scheme that has been tailor made to the specific needs of the client, taking local supply and demand factors into consideration. It is a highly energy efficient scheme comprising of desulphurisation, primary and secondary reforming, two-step shift conversion, OASE (aMDEA) $CO_2$ removal, compression, methanol synthesis loop, high pressure methanation, S-300 ammonia synthesis loop, membrane hydrogen recovery unit, and product recovery. The process layout is illustrated in Fig. 15.

A number of special features have been introduced in order to be able to produce synthesis gas of the right quality as needed for the methanol synthesis unit. Part of the synthesis gas is as such by-passing the HT shift, the LT shift and the $CO_2$ absorber in order to adjust the $CO/CO_2$ ratio for the downstream methanol synthesis, which is located between the two compressor casings of the ammonia synthesis gas compressor. One of the advantages of an IMAP™ co-production plant is that the pressure drop in the front-end of the plant is lower than in a normal ammonia plant due to the fact that the methanation takes place at high pressure as being explained in more detail below.

Downstream of the $CO_2$ absorber, the synthesis gas is being compressed directly in the first casing of the synthesis gas compressor to the methanol loop pressure. The methanol synthesis is being favoured by high pressure, and high $CO/CO_2$ ratio, and the methanol loop pressure is in this case given by the inter stage pressure in the synthesis gas compressor. This so-called "in-line" once-through scheme results in a high conversion into methanol compared to other possible schemes.

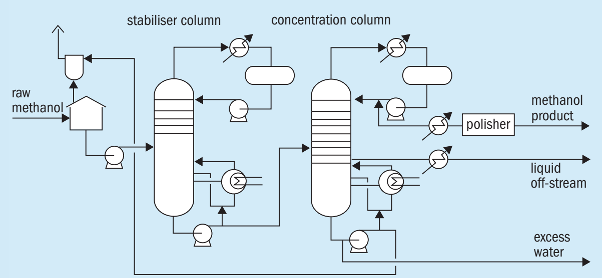
Methanol reaction takes place in two methanol reactors. First a boiling water reactor is used to handle the bulk conversion of the very reactive synthesis gas into methanol. By using a boiling water reactor, the peak temperature in the reactor can be kept low despite the strongly exothermic methanol reaction, and the by-product formation can be controlled and kept at the desired level. The boiling water reactor comprises a number of catalyst filled tubes, and the reactor is cooled on the shell side by boiling water. After separation of the methanol product exiting from the boiling water reactor, the remaining synthesis gas, which is not so reactive as the raw make-up synthesis gas, is passed on to a simple adiabatic methanol reactor, in order to improve the overall conversion of synthesis gas into methanol.

After the two methanol reactors the majority of the CO and the $CO_2$ has been converted into methanol, and only minor traces of CO and $CO_2$ is left. These components have to be removed before the synthesis gas can enter the ammonia synthesis loop because they are poisons for the downstream ammonia synthesis catalyst. A high pressure methanation reactor is used for converting the final traces of CO and $CO_2$ into $CH_4$ which is an inert in the ammonia synthesis loop.

The raw methanol produced in the two methanol reactors is sent to the distillation section for further purification. The distillation section comprise a layout with two columns, a stabiliser column to separate various low boiling point components like for example DME from the methanol/water mixture, and a concentration column where in particular high boiling compounds like higher alcohols are being separated. Final specification of the product is according to the GHOST norms. Heat input for the columns is supplied from reboilers. The stabiliser column reboiler is fired by the exit gas from the boiling water reactor, whereas the concentration column is fired by low pressure steam. Fig. 16 shows details of the methanol distillation section.

Generally, the idea of having a plant that can produce multiple products is very attractive. The product flexibility can be used in situations with fluctuating product prices, and the plant owner will have the possibility to diversify the product from ammonia and urea to methanol to minimise the impact on price cycles. Furthermore, in cases with a regional demand for methanol, a co-production plant is a way to get a relative small methanol plant constructed at a competitive cost taking benefit of the economy of scale that is normally applicable for much larger plant capacities (see the graph on page 8 for historic price trends for ammonia, methanol and urea). The methanol price has been particularly high in certain periods of 2006 and 2007 and 2014. ■

Fig 16: **Methanol distillation section**




*Source: MHI/Topsoe*

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